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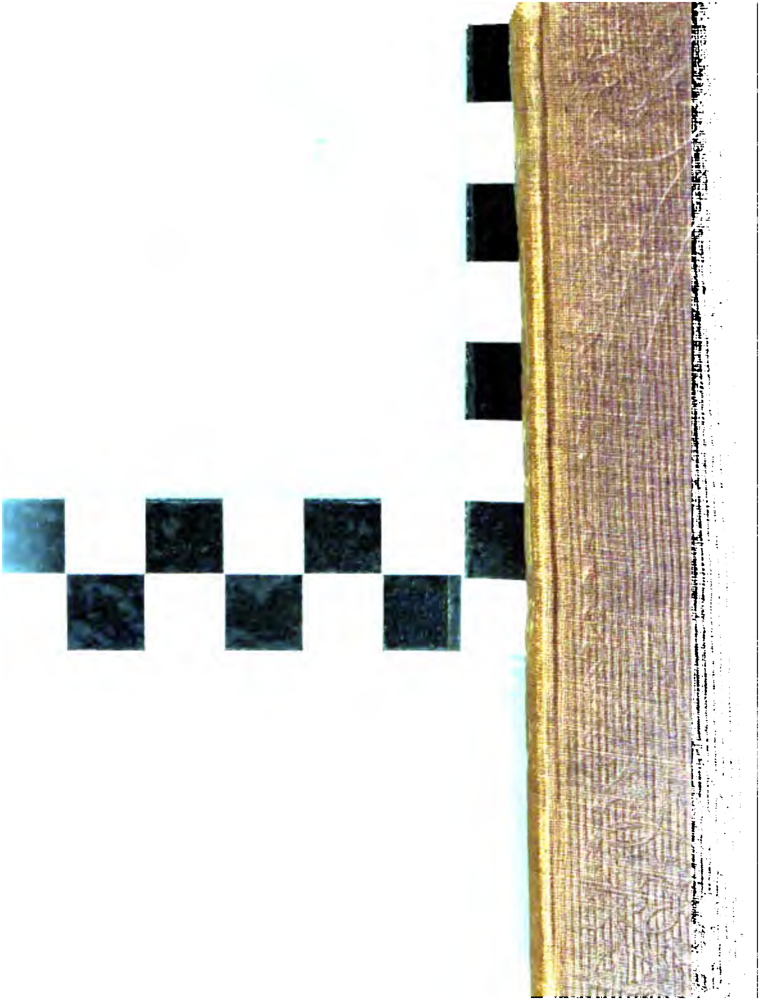

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323.

HEAT:

ITS

SOURCES, INFLUENCE, AND RESULTS.

> Nor to the surface of enlivened earth,
> Graceful with hills and dales, and leafy woods,
> Her liberal tresses, is thy force confined:
> But, to the bowelled cavern darting deep,
> The mineral kinds confess thy mighty power.
> Effulgent, hence the veiny marble shines;
> Hence labour draws his tools; hence burnished war
> Gleams on the day; the nobler works of peace
> Hence bless mankind, and generous commerce binds
> The round of nations in a golden chain.
>
> THOMSON.

LONDON:
THE RELIGIOUS TRACT SOCIETY;
Instituted 1799.
SOLD AT THE DEPOSITORY, 56, PATERNOSTER ROW,
AND 65, ST. PAUL'S CHURCHYARD; AND
BY THE BOOKSELLERS.

1841.

323.

TRAVELLERS RESTING AT NOON.

HEAT:

ITS

INFLUENCE AND RESULTS.

[illegible]

LONDON:

THE RELIGIOUS TRACT SOCIETY;

[illegible], PATERNOSTER ROW; [illegible] various effects around us, which we cannot fail to notice. But if the question be proposed, What is heat? this inquiry is like many others: a child may propose them, but they can only be solved by extensive knowledge; and there are instances in which even that is not enough.

The fact is, that while it is not always an easy task to distinguish between cause and effect, it is much more difficult to discover a cause which can be said to satisfy the human mind. There is a great First Cause; of him we have some knowledge from the works of his hands, and the revelation He has given of himself; but of the final causes which He has established, the wisest of men confess themselves to be ignorant. Who will tell us the cause of motion in a thousand instances? The philosopher says, that he has discovered the origin of a certain appearance to be motion; but the origin of the motion he is, in most cases, unable to ascertain. It may, however, be traced to certain agents called heat, light, electricity, or magnetism; but what are they? For nearly six thousand years the human race have been acquainted with many effects which are said to be derived from these causes, such as reflexion from the surface of water and polished metals, the sensation of heat received from the sun, and the lightning which flashes in the heavens; but the philosophers of the present day are almost as incapable of describing their origin as the man who first studied natural appearances.

It will, however, be expected that some answer should be given to the apparently simple question, What is the cause of heat? Here, then, the subject is one of great difficulty—one upon which the wisest can only speculate. But it may be interesting to know what opinions have been formed by those who have applied themselves diligently to the study of science. No person, perhaps, who has examined carefully the cause of heat, would assert that his view of it must be the best, or even that he was perfectly satisfied with the explanation he would offer of well-known appearances; he would rather say, that it better accounted for facts than any other with which he was acquainted; and such a reply is often the course of true wisdom.

Two theories as to heat have been proposed, and both have still their supporters: according to one, it is an exceedingly subtile fluid, residing in all bodies, but capable of emission and re-entrance; while according to others, it is not a material agent, but the effect of certain motions among the particles of matter.

It is a strong argument in favour of the former, that heat may be communicated from one body to another through a vacuum—a space deprived of air. Pictet suspended a thermometer, or heat-measurer, in an exhausted receiver, that is, a glass vessel from which the air is withdrawn, and found that there was a change of temperature; and from this he concluded, that heat is a material agent, and capable of motion through a vacuum. Count Rumford performed a similar experiment, and came to the same conclusion. This philosopher suspended a thermometer in a Torricellian vacuum, and found that it then showed changes of temperature just as in the atmospheric air, rising and falling in a similar and equal degree.

As the term Torricellian vacuum will not be understood by every reader, a short description may be desirable. Some years since, no scientific explanation could be given of the rise of water in a pump; and to hide ignorance, it was said, and commonly received by philosophers, that nature abhorred a vacuum; in other words, that matter filled all space. It happened, however, that a pump at Florence was fixed at a height of more than thirty-two feet above the water in the well, and the water would not rise when the air was withdrawn by the sucker, or piston. Galileo, the celebrated philosopher, was asked the cause of this, but could give no reason. Torricelli, who had been the pupil of Galileo, and was at the time a professor of philosophy, studied this subject closely, and came to the just conclusion, that water rises in the pump when the air is withdrawn, because it is pressed upon by the atmosphere; and not to a greater height than thirty-two feet, because the pressure of the air and of the water are then equal, and they balance each other. To test the truth of this supposition, he resolved to try the effect with mercury; and filled a tube, open at one end and closed at the other, with this metal. He computed that the height of such a column would be about twenty-eight inches, and he had the gratification to see the mercury become stationary at this very point. Now, the space at the top of the tube in this experiment being destitute of air, for, prior to being inverted, it was occupied by mercury, is called a Torricellian vacuum. But, though it is true that in such a case there is no air, it is not true that all matter is absent, for there is a vapour of mercury. This vapour was considered by Count Rumford too rare to transmit vibrations, and hence he concluded that the space was traversed by the particles of heat, a material agent.

Many attempts have been made to ascertain whether bodies become heavier as their temperature is raised, and lighter as they cool. Dr. Fordyce made some experiments, which led him to believe that heat did increase the weight of bodies; and some other scientific men came to the same conclusion: but it is now conceded that there is no increase of weight from increase of temperature, which cannot be traced to known effects produced on the atmosphere or on the thermometer.

If it be admitted that heat is a fluid, its chief results are easily explained. Thus, in the warming of any body, we may imagine it to be so formed as to allow heat a ready passage, while, in other instances, there may be a resistance to its progress. On this supposition, bodies expand when heated, because the fluid enters and separates the particles, driving them more and more asunder, until the solid becomes a liquid, as when ice is changed into water, and the liquid becomes a gas,—as when water, on boiling, passes off in steam. If heat is not a substance, it must be a quality, and this quality can only be motion. In this Sir Isaac Newton supposed it to consist, but to his opinion there are many and serious objections.

Here, then, let us learn a lesson of humility. The pride which many display proves they can have no true knowledge. The more we attain, the more shall we see that much remains unknown, as the prospect widens in proportion to the traveller's ascent of the hill. Humility prepares us to advance in human learning; nor can we, without it, become acquainted with the things of God, since Christ has said, "Whosoever shall not receive the kingdom of God as a little child, he shall not enter therein," Mark x. 15. With entire submission to his Divine authority, then, may every reader be found sitting, like Mary, at the feet of Jesus.

CHAPTER II.

SOURCES OF HEAT.—CONDENSATION.—FRICTION.—PERCUSSION.—CHEMICAL CHANGES.—THE SOLAR RAYS.—ANIMAL HEAT.

Although the varieties of matter are almost innumerable, all substances may be divided into two classes, solids and fluids. Of fluids there are two kinds; one called liquids, the other gases. Gaseous bodies are, also, denominated elastic fluids, because they will easily yield to pressure; but, when that pressure is removed, they have an equal degree of expansion. With elasticity every one is acquainted, in the rebounding of India-rubber and other substances.

It may also be mentioned, that while some elastic fluids retain their state under all pressures, and at all temperatures, there are others which very readily become liquids. The atmospheric air, for instance, cannot, by any means at present known, be reduced to a liquid state; but steam is easily condensed, and then becomes water. The former class of elastic fluids comprehends all the gases; the latter all the vapours.

It is true, that some of the gases may, under great pressure, be reduced to the liquid state, but not under common pressure, like the vapour of water, mercury, alcohol, and other substances.

It is thus evident, though there is a great difference in the form and appearance of substances, that they may be arranged under the classes already mentioned. All matter, however, is equally acted upon by natural agents. Of these heat and electricity appear to be the most important; and so universally are they distributed, that we can scarcely conceive the existence of matter, or, at least, how there can be any change of condition, without them.

It is to one of these agents, heat, that the attention of the reader is now to be particularly directed. What heat is we do not pretend to determine. Two theories have been proposed, and both have their advocates. Some, as has been seen, imagine it to be a fluid, existing in all substances, and called into action according to circumstances; while others believe it to be merely the effect of some change in the particles of matter. Those who adopt the former notion make a distinction in terms between the agent and the effect, the former being called caloric, the latter heat. Thus we may speak of the heat of a body, because it is an effect produced upon that body; but when referring to the agent which caused that effect, it is called caloric. It has not, however, been thought necessary to make this distinction in the following pages; for the reader will be able to distinguish between the cause and the effect, and the adoption of different terms would prove inconvenient.

These general remarks will prepare the mind for an inquiry as to the means by which heat may be developed, or, in other words, by which the temperature of substances is raised. The word temperature here should not be misunderstood, or applied to more than it is intended to signify. When the heat of any substance is developed, or, being developed, is communicated to any other body, its temperature is said to be raised: and when heat is abstracted, its temperature is said to be lowered. This temperature may be measured by the thermometer, and, to a certain extent, by the touch. But when the temperature is said to be a certain number of degrees, as 60, or 80, or 100, we do not mean that the substance spoken of contains no more heat than is represented by these numbers, but merely that so many degrees are made sensible: we shall see hereafter that they afford no criterion whatever of the quantity of heat contained in the substance. Thus, for instance, the temperature of a river, a lake, or a sea, may be seventy or eighty degrees, and that of a wine-glass full of the water of any one of them, will be the same when a thermometer is plunged in it. But it cannot be for a moment supposed, that the water in the glass contains as much heat as the water in the river, the lake, or sea. The temperature, therefore, is but the degree of sensible heat, and only in this sense is the term employed.

The temperature of bodies is increased, or, in other words, heat is developed, by a variety of causes, such as condensation, friction, percussion, chemical changes, electricity, galvanism, combustion, solar light, and by the animal body; these it will now be desirable to examine.

Heat, then, is produced by condensation. Whenever a substance is condensed, or compressed, heat is developed, and the temperature is increased. Of this, many familiar examples might be given. When a blacksmith hammers a piece of cold iron on his anvil, it soon becomes hot; and if he continues his blows, the iron will be raised to a red heat. This is an effect entirely owing to the compression of the particles of iron into a smaller space. In like manner, if a metallic or strong glass tube, closed at one end, be taken, and a solid piston be forced down it, the enclosed air will be compressed, and give out so much heat as to light a piece of German tinder fixed to the bottom of the piston. In every instance of compression or condensation, heat is developed — a fact which, if borne in mind, will frequently enable an observer to account for effects otherwise inexplicable.

Again, the temperature of bodies is in all cases raised by friction. It is stated by travellers, that in some parts of the world, where the land is in an uncultivated state and covered with forest trees, the friction between the branches of contiguous trees, rubbed together by the waving motion given to them by the wind, frequently inflames them; and the fire being once kindled, is communicated from one tree to another until the whole forest, perhaps extending for miles, is reduced to ashes. This fact led one of our poets to say:

So when the storms through Indian forests rave,
And bend the pliant canes in curling wave,
Grind their siliceous joints with ceaseless ire,
Till bright emerge the ruby seeds of fire;
A brazen light bedims the burning sky,
And shuts each shrinking star's refulgent eye;
The forest roars, the crimson surges play,
And flash through lurid night infernal day;
Floats far and loud the hoarse discordant yell
Of ravening pards, which harmless crowd the dell;
While boa-snakes, to wet savannahs trail
Awkward, a lingering length of tail;

The barbarous tiger whets his fangs no more,
To lap, with torturing pause, his victim's gore;
Curb'd of their rage, hyenas gaunt are tame,
And shrink, begirt with all-devouring flame.

The wandering savage, who roams from place to place in quest of game, or to satisfy his love of change, has no other means of procuring a flame to kindle his fire, for warmth or the operation of cooking, than by rubbing two pieces of dry wood together until they inflame; and in this he is, from habit, generally exceedingly expert, producing a sufficient heat for this purpose in a few minutes. The missionary travellers, the late Rev. D. Tyerman and G. Bennet Esq., have described the simple and ingenious process by which the islanders of Tahiti obtain fire. On one occasion they observed a man take a piece of dry purau wood, twelve inches long and two thick. With another stick of the same tree, sharpened to a point, and held with both his hands, at an angle of about forty-five degrees, he rubbed the former gently as it lay on the ground, till he had scratched a groove in it several inches long. Then, continuing the same operation, but pressing the point harder on the lower piece, and increasing the velocity of the motion, some tram dust was soon formed within the groove, and collected at one end. In a few seconds smoke was apparent, and the dust was ignited. The spark was then immediately conveyed into a finger hole opened in a handful of dry grass. The man blew upon it, and waving the tuft in the air, the grass was quickly in a flame. The whole process did not occupy more than two minutes.

In cold, frosty weather, we rub our hands together, as we say, "to produce circulation," but, in fact, to obtain a superficial heat by friction; and the bodies of persons, whose vital functions are suspended by drowning or other circumstances, are rubbed for the same reason. Heat from friction is also exhibited in the wheels of carriages taking fire, and in the high temperature of certain parts of machinery when in rapid action.

In the whale fishery, whenever the prey lies on the surface of the water, unconscious of the approach of its foes, the hardy fisher rows directly upon it, and the instant before the boat touches it, buries his harpoon in its back. In the surprise and agony of the moment, the wounded whale makes a convulsive effort to escape; and the rapidity with which it draws out the line attached to the harpoon, occasions so much friction while passing over the edge of the boat, as often to envelope the harpooner in smoke, and it is only by pouring water on the wood, that it is kept from catching fire. In like manner, if the reader has witnessed a ship-launch, he has not failed to observe, that just as the vessel is gliding along the sloping timbers, a dense smoke arises from the friction that is produced.

Percussion must be mentioned as a source of heat. It is not improbable that the effects thus resulting are to be traced to condensation, yet the instances of the development of heat by the two processes are sufficiently distinct to be separately mentioned. The most common example of the increase of temperature from percussion, is found in the familiar but useful instrument called the tinder-box. It consists, as every reader is aware, of a tin box, containing some burnt rag. By striking a flint against a piece of steel, small pieces of the former are broken off at a red heat, so that the sparks falling on the tinder, put it in such a state of low combustion as to inflame a match. The shower of sparks when the materials are good, is abundant and brilliant. Another instance of the same kind occurs, when sparks are struck by the shoes of horses striking in their rapid movements against the flints of our common roads.

Chemical changes, as productive of heat, must not be overlooked. Few substances found in nature, or employed in the arts, are in a simple state, nearly, if not quite all, are compound bodies, consisting of two or more elementary principles. Thus flint and quartz rock consist of two simple substances, one a metal called silicium, the other a gas called oxygen: lime consists of calcium and oxygen; and wood, of carbon, blended with many other substances. Hence it is that when two compound bodies are placed in contact with each other, or are mixed by solution, chemical changes occur; the element united with one substance leaving it and joining the other. These changes are said to be the results of chemical affinity. A few instances may now be mentioned in which heat is developed, and a change of temperature produced.

If a quantity of sulphuric acid is poured into a vessel of water, the temperature will be raised; by increasing the amount of the acid, the temperature of the mixture may be brought to nearly the boiling point.

If water be poured upon a piece of quick lime, though both substances may have, at the time, a temperature equal to that at which water freezes, a heat greater than that of boiling water will be produced. In this experiment the effect may be traced to the passage of water from a liquid to a solid state, uniting chemically with the lime, and giving off what is termed its latent heat, which will hereafter be explained.

If, too, a portion of sulphuric acid and nitric acid be mixed together in a cup, and the mixture poured into another cup, containing a small quantity of oil of turpentine, so violent a chemical action is produced, that the whole will burst forth into a brilliant flame.

Two opinions have been held in reference to the sun as a source of heat, one regarding that orb as a mass intensely heated, as metals often are; the other regarding heat as a state of an ethereal fluid, pervading all space, and that the sun may produce its light, as well as heat, without any loss, as a bell suffers not from its giving forth sound. But whether the light with which our atmosphere is filled is thrown from the sun in rays, or whether it is an independent fluid, acted upon and made luminous by the sun, scientific men are not even now agreed. It has, however, been proved, by experiment, that light is composed of seven primitive colours, and that some of these have a heating effect.

The burning glass, which the schoolboy uses in sport, and to which the hunter is sometimes indebted for the fire he kindles at the foot of the mountain, is a familiar illustration of this fact; and it appears, also, in many phenomena of the natural world. Let us look, for instance, at the season of winter. Nearly the whole vegetable, and a great part of the smaller tribes of the animal world, are then lying buried amidst the darkness and desolation of that period. The eye, accustomed to observation, looks abroad from day to day, but only to behold the face of the earth in its torpor and sterility. The hills and the valleys, once clothed with variegated beauty, exhibit scarcely a vestige of their rich attire: it seems almost as if the pulse of life stood still. But, when spring comes, a change which, apart from its familiarity, would be truly astounding, bursts on the view. Nature starts again into life and splendour, for God has given the word, and a genial warmth is diffused around, scattering blessings through air, and earth, and water. The sun, the great depository of light and heat, is as a giant coming forth from his chamber, and rejoices as a strong man to run a race, and beneath his precious influences the wilderness and the solitary place become glad, and the desert rejoices and blossoms as the rose. It is as if there were a resurrection from all the chambers of the dead, except the sepulchres of men; and every breeze bears on its wings millions of newly awakened creatures, to enjoy for their appointed time the elements around.

To adopt the words of our poet Thomson:

Go, see where surly winter passes off,
Far to the north, and calls his ruffian blasts:

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His blasts obey, and quit the howling hill,
The shattered forest, and the ravaged vale;
While softer gales succeed, at whose kind touch,
Dissolving snows in livid torrents lost,
The mountains lift their green heads to the sky.
——————— Now no more
The expansive atmosphere is cramped with cold;
But, full of life and vivifying soul,
Lifts the light clouds sublime, and spreads them thin,
Fleecy, and white, o'er all surrounding heaven.
The hawthorn whitens; and the juicy groves
Put forth their buds, unfolding by degrees,
Till the whole leafy forest stands display'd,
In full luxuriance, to the sighing gales;
Where the deer rustle through the twining brake,
And the birds sing conceal'd.

Another poet says:

Sweet are the omens of approaching spring,
  When gay the elder sprouts her winged leaves;
Then tootling robins carol-welcomes sing,
  And sparrows chirp glad tidings from the eaves.
What lovely prospects wait each wakening hour,
  When each new day some novelty displays.
How sweet the sunbeam melts the crocus flower,
  Whose borrow'd pride shines dizen'd in his rays!
Sweet, new-laid hedges flush their tender green;
Sweet peep the arum-leaves their shelter screen;
Ah! sweet is all that I'm denied to share;
  Want's painful hindrance holds me to her stall,
But still Hope's smiles unpoint the thorns of care,
  Since Heaven's eternal spring is free from all.

When man was innocent, he saw God in all the objects around, and offered him, with the highest admiration and supreme affection, the tribute of praise. It is a striking proof of our "fall from original righteousness," of the darkness of the natural mind, and of the hardness of the human heart, that the following reproof should be so generally deserved:

> What prodigies can power Divine perform
> More grand than it produces year by year,
> And all in sight of inattentive man?
> Familiar with the effect we slight the cause,
> And in the constancy of nature's course,
> The regular return of genial months,
> And renovation of a faded world
> See nought to wonder at.

How manifest is it that we need the operation of that Almighty power to which Christ refers: "Verily, verily, I say unto you, The hour is coming, and now is, when the dead shall hear the voice of the Son of God: and they that hear shall live!" John v. 25. He alone can quicken us, who are "dead in trespasses and sins." The soul is thus prepared to yield all "the fruits of the Spirit;" it becomes as "a field which the Lord hath blessed," while those who, from the love of sin, remain careless and insensible, are "condemned already."

The influence of the solar rays, just referred to, reminds us that there is a regular gradation of temperature, from the surface of the earth to the upper regions of the air; and for every hundred and ten yards of ascent, the heat diminishes as much as if we were to advance one degree of latitude towards the northern polar regions. The city of Quito, on the Andes, is almost under the equator, and yet, owing to its elevation, the air of that city differs little in temperature from that of Paris.

It is natural to inquire into the causes of this variety. There are several; but all resolvable into the relative position of the different places with regard to the sun, or rather their different exposure to the action of the solar rays. When they fall directly or vertically on any particular district, they give out much more heat than when they fall obliquely; for they not only strike with greater force, but a larger number of them are included in the same space. Here is a circumstance well deserving remembrance. Another is the greater length of time that the solar rays act at once upon a particular spot or country, and, consequently, diffuse a proportionately greater amount of heat. These two causes will account for the general fact of the diminution of temperature from the equator to the poles, and for the difference between our summer and winter.

The greater or less reflection which the rays of heat undergo has some share in producing this diversity, as have also the different capacities of soils to absorb them. The vicinity of the sea, too, it is well known, has a great effect in modifying and equalizing the temperature, and on this account the interior of continents is colder than their coasts; so, likewise, in the coldest winter season, the temperature of Edinburgh is said to be some degrees warmer than that of London.

The effect of climate on the human frame is worthy of remark; and lamentable is it that in some parts of the earth, so strong and unjust a prejudice is cherished against not merely a sable but a coloured skin. This is even displayed notwithstanding the possession of great moral worth. Thus, in a letter received some time ago, dated Ann Harbour, Michigan, from Mr. Metzgar, a Lutheran clergyman, there is an account of the disrespectful conduct manifested towards Mrs. Metzgar, simply because the colour of her skin was less fair than certain persons had been accustomed to. Now, it is worthy of remark, that a statement was made by Sir Everard Home, some years since, on the utility of the black substance in the skin of the negro, in preventing the scorching operation of the sun's rays; and as we know that nothing tends more to the removal

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A TROPICAL SCENE.

of prejudice, than the rectification of the judgment upon those points on which it may have been warped by false impressions, it is possible that some might be induced to look with respect and benevolence on those they have hitherto slighted, when they consider that the very colour which has awakened contrary dispositions, is an indication of the peculiar care of our heavenly Father over this portion of our fellow creatures.

Sir Everard Home showed, at a meeting of the Royal Society, that by exposing the back of the hand, or other parts of the body, to the sun's rays, they become irritated and inflamed; small specks or freckles first appear, and these, on continual exposure, rise into blisters. The same is true, if the flesh be covered with thin white linen; but if the body be covered with a piece of black crape, though it will be hotter when exposed to the sun, yet the rays will no longer produce blisters. Thus the injurious effect of the heat of the sun may be prevented by an artificial blackening of the skin. How strongly does this show that the black man, though too often contemptuously treated by his fellow creatures, is not beneath the notice of his Creator! Rather may we consider him as continually carrying about with him, in the colour of his skin, the memento of our heavenly Father's mercy.

Every plant and animal is adapted by Him who cannot err, to the circumstances in which it is placed; no wonder, then, that man should be. Bishop Heber says, during his residence in India, where the dress and habitations of the natives are alike adapted to that sultry clime:—" It is true, that in the negro are other peculiarities to which the European colonists show no approximation, and which undoubtedly do not appear to follow so naturally from the climate, as that swarthiness of complexion which is the sole distinction between the Hindoo and the European. But if heat produces one change, other peculiarities of climate may produce other and additional changes; and when such peculiarities have three thousand or four thousand years to operate in, it is not easy to fix any limits to their power. I am inclined, after all, to suspect that our European vanity leads us astray in supposing that our own is the primitive complexion, which I should rather suppose was that of the Indian, half-way between the two extremes, and perhaps the most agreeable to the eye and the instinct of the majority of the human race. A colder climate, and a constant use of clothes, may have blanched the skin as effectually as a burning sun or nakedness may have tanned it. Thus, while hardship, additional exposure, a greater degree of heat, and other circumstances with

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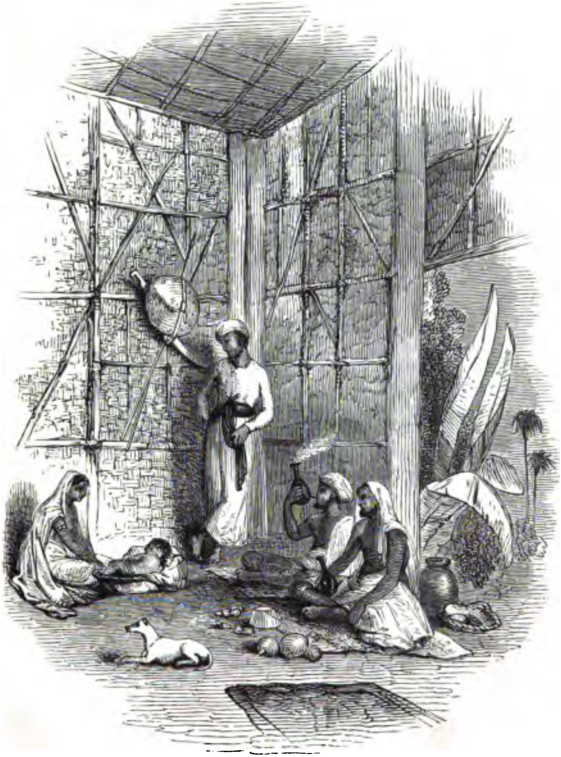


INDIAN COTTAGE.

which we are unacquainted, may have deteriorated the Hindoo into a negro, opposite courses may have changed him into the progressively lighter tints of the Chinese, the Persian, and the European."

To refer now to inferior creatures, it is worthy of remark, that the Creator has destined them to breathe water while living in it, thus rendering them incapable of producing the same heat as those that live in the air. Here, however, Infinite Wisdom has removed every difficulty; for it is so ordered, that vital action is performed in the one case as completely as in the other. Still further, knowing only the warm animals, or the cold ones imperfectly, we should have thought that a much lower temperature than that in which they exist would have destroyed life; but in this case also, the Divine provision is appropriate and complete. All the warm-blooded fishes are of large size, and many of huge bulk, thus opposing the process of cooling; while a thick covering of fat, aiding also their needful buoyancy, protects the essential heat of the vital organs.

In flying insects, their smallness, and the rapidity of their motions, would have rendered the preservation of a high animal temperature difficult to the highest human wisdom, but for them also Divine care has been manifested. They are chiefly concerned with plants, and these are, for the most part, dependent on the higher temperatures.

The heat of birds has been raised higher than our own. If, as is thought, their temperature depends on the greater quantity of air which birds respire, and if, also, though this is not proved, their great muscular power depends on the same cause, then, as in other cases, many ends have been gained by one contrivance. If the power of producing this high temperature also compensates for the cooling of birds in their rapid passage through the air, an additional one is found in their remarkably warm clothing. This is still more apparent in the case of sea-birds, while it offers a striking contrast to fishes, which want no such protection.

It is probable that most of those animals which have their centre of dominion in temperate countries are capable of enduring the most widely-extended geographical distribution. This may be illustrated even by the different varieties of the human race. A native of Britain braves alike the most fiery breath of the torrid zone, and the frozen climate of Greenland; but an Esquimaux would perish on the shores of the Congo; and a negro, although better supplied than Russian sailors under similar circumstances, would hardly survive amid the desolate snows of Spitzbergen.

Most of those animals which we have domesticated, and carried along with us in our almost universal migrations, such as the horse, sheep, and goat, have their origin in the temperate countries of higher Asia, among the mountains and elevated plains of which their originals are still to be traced. It is, no doubt, owing to the physical conditions of clime and country, that these, and certain other species, have been enabled to follow their masters, and to breed and prosper under almost every variety of climate. On the other hand, had they been natives of an equatorial region, they would have been comparatively of little service in the northern parts of Europe or America; or had they been naturally confined to the vicinity of the Arctic circle, their value would have suffered a corresponding diminution in relation to the inhabitants within the tropics. It is thus, by an admirable law of Divine benevolence, that all those animals, from the domestication and culture of which the most widely-spread and essential advantage was capable of resulting to the human race, have been created and retained the natural inmates of the temperate regions of our globe; while those, again, the general distribution of which would have been regarded rather as a curse than a blessing, have been, with few exceptions, made to dwell in either the hottest or the coldest climes. Let us take, by way of illustration, an example from each of the two extremes. Were a tiger conveyed from the thick and warm jungles of tropical Asia to the northern steppes of Siberia, or the shores of the Arctic Sea, how soon would he lose his gigantic strength and ferocious vigour! Or, were a Polar bear transferred from his floating icebergs, to a sultry island of the Indian Archipelago, how speedily would the surly savage cease to create alarm! The spirit of the same observation might be applied to much more serviceable animals, which, however, not being natives of temperate countries, are, for that very reason, incapable of being rendered useful in the most extensive, and, therefore, the highest degree. We may adduce, as familiar examples, the rein-deer and dromedary; the former of which, the wandering Bedouin of the desert would as soon attempt to rear amid the shifting sands of Arabia, as the nomadian of the north would the latter in the cold and lofty plains of Finmark or Norway.

Let us now look at another and most beneficent law of the all-wise Creator; it is that by which the bodies of living animals, resembling, in some degree, living vegetables, are able to preserve, in themselves, a certain temperature, even when surrounded by bodies that are colder or hotter than they. The natives of India, who feel the slightest covering a burden, have yet a natural warmth resembling our own; and, what is more extraordinary, a warmth similar to that of our polar voyagers, who, in the distant regions of the north, were inhaling air that would freeze mercury.

Sir E. Parry states, that during the most intense degree of cold marked by the spirit thermometer during his stay with his associates, in Winter Harbour, not the slightest inconvenience was suffered from exposure in the open air by a person well-clothed, so long as the weather was perfectly calm; but, in walking against a very light air or wind, there was a smarting sensation all over the face, accompanied by a pain in the middle of the forehead, which soon became rather severe. They amused themselves in freezing some mercury, during the continuance of the cold weather, and by beating it out on an anvil, previously reduced to the temperature of the atmosphere. In this state it did not appear to be very malleable, usually breaking after two or three blows of the hammer.

Is it not marvellous, then, that there should be not merely the exact temperature required, but an invariable degree for each of many different races? It may be assumed, for the sake of simplicity, that the heat of warm-blooded animals is one hundred degrees. Nor is this all, for as the variations of external temperature must interfere with the quantity produced, other arrangements are required to supply a deficiency, or to correct excess. Here is one of the most surprising things in nature, that under differences of temperature ranging through much more than a hundred degrees, so small a body as that of most animals should remain at the same point, or at least be able to restore itself to its proper degree, under the various accidents by which it is affected.

The singular power with which the body is endowed of enduring great heat, and of breathing air of high temperature, has been shown in curious experiments made by a party of distinguished men. Sir Charles Blagden entered a room having a temperature of one hundred and ninety-eight degrees, and remained ten minutes. Dr. Solander found the heat two hundred and ten degrees, and Sir Joseph Banks entered the room when it was two hundred and eleven degrees, and yet their bodies preserved their natural temperature. Sir C. Blagden, on touching his side, found it cold like a corpse, and yet under his tongue the heat was ninety-eight degrees; and hence they concluded that the body has the power of destroying a certain degree of heat when communicated with a certain degree of quickness. The same gentleman encountered a still warmer temperature. Sir C. Blagden went into a room where the heat was rather above two hundred and sixty degrees, and stayed there eight minutes, sometimes walking about to all parts of the room, but chiefly standing still where the heat was two hundred and forty degrees; still he suffered no pain, and thought he could support a much greater heat. For seven minutes Sir C. Blagden's breathing was uninterrupted, but afterwards he felt his lungs oppressed, and he retired, his pulse being at one hundred and forty-four, double its usual quickness.

Ample proof was afforded of the high temperature endured. Some eggs and a beefsteak were placed on a tin frame near the thermometer, but further from the entrance than from the wall of the room: in the space of twenty minutes, the eggs were roasted quite hard, and in forty-seven minutes the steak was almost dry. Another beef-steak, in a similar place, was rather over-done in thirty-three minutes.

This chapter may, therefore, be properly concluded with a reference to one of the most extraordinary sources of heat, the animal body, but by what process the necessary temperature is produced and maintained, is still a matter of conjecture.

Every one must be aware that the bodies of all animals are warmer during life than after death, but not many have thought of inquiring into the cause of this singular fact. Physicians themselves are not agreed in opinion; but it is desirable that the reader should know the extent of their investigations, and the amount of their knowledge.

Dr. Crawford was the first who proposed, in a reasonable manner, to account for the production of animal heat. To understand this, however, it is necessary to know something of the circulation of blood in the animal body; but this information may be given in a few words. The blood is propelled from the heart through vessels or tubes called veins, and after being conveyed to every extremity of the body, is brought back to the heart by another system of vessels called arteries. But in making this circuit, the blood is changed in character and appearance, for in the veins it is dark-coloured, we might almost say black, and in this condition is called venous blood, while in the arteries it has a florid hue, and is called arterial blood. Now, this change is produced in the lungs, through the medium of the air in the act of respiration, and it is effected by the absorption of oxygen gas, which is a component part of atmospheric air, and by the giving out of carbonic acid gas which it has collected in its progress.

Dr. Crawford founded his theory to account for the production of animal heat, on this fact. The carbon of the venous blood uniting with the oxygen of the air forms carbonic acid, and it was then supposed that this gas had less capacity for heat than the atmospheric air, so that at the moment of combination, heat was disengaged. On the other hand, the blood being changed from venous to arterial, was supposed to have a greater capacity for heat, which caused it to absorb that given out during the formation of carbonic acid. Thus, it was imagined, a continued supply of heat was provided for the animal body. This theory is very ingenious; but as it has been proved, by recent investigations, that the carbonic acid and atmospheric air have not that difference in the capacity for heat which was before imagined, it can no longer be maintained, and we must seek for some other cause more consistent with the acknowledged principles of nature.

Sir Benjamin Brodie traces the production of animal heat entirely to the action of the nervous system, and considers it altogether independent of the chemical changes which take place in the lungs. His opinion is not beyond dispute; for although the experiments made by Sir Benjamin are favourable to his theory, others have been since performed which make it less satisfactory.

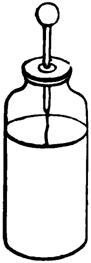
In the year 1839, another theory was proposed by Dr. Winn, which is now engaging much attention. According to it, the animal heat is probably maintained by the incessant expansion and contraction of the arteries during life. To this conclusion Dr. Winn was drawn, by observing that a piece of caoutchouc had an increased temperature after it had been suddenly stretched, of which any reader may have full proof by stretching a piece of india-rubber which is applied to the face. From the experiments made, it appears probable that the heat so necessary for the existence of the animal body is produced in this simple manner; and upon this supposition it is easy to account for the variations of temperature arising from exercise, fevers, the approach of old age, and all the other circumstances which are known to influence it.

CHAPTER III.

ELECTRICITY, A SOURCE OF HEAT — THE LEYDEN JAR — THE THUNDER-STORM—THE VOLTAIC BATTERY—COMBUSTION.

OTHER sources of heat remain to be noticed—one is electricity. There are many ways of exhibiting its effects, some of which may now be briefly noticed. The agent called electricity, be it remarked, exists in all bodies, and may be disturbed and put in motion by various means, such as friction and the chemical action between different substances. Through some bodies this free electricity finds a ready passage, while others resist its progress altogether, or give it a passage with great difficulty. The metals, for instance, are good conductors, and dry atmospheric air is a non-conductor. If a current of electricity, which term may be with propriety used, the agent being considered a fluid, should have to pass through any extent of atmospheric air in its passage from one body to another, a resistance is offered, and heat and light are produced.

The instruments by which electricity is commonly obtained, are called the electrical machine, and the galvanic or voltaic battery; and by the use of either of these, the effects of heat may be shown. The electrical machine consists of a cylinder, or plate of glass, so fitted up as to receive from the hand a rotatory motion, that there may be a friction between the glass and a cushion, called the rubber, and consequently a setting free of electricity. This free electricity may be received, or, to use the common expression, accumulated, in glass vessels, coated with tin foil, and called Leyden jars. To the top of the jar is fitted a wooden cover, through which a brass wire is passed, touching the inner coating, and having a knob at the other end, as shown in the figure. If this brass ball be brought near to the conductor of the machine, when in rotation, the electricity will enter and charge the interior coating of the jar with that fluid. When this is done, if the knob which communicates with the interior of the jar be connected with the exterior coating by any means which may be easily applied, such as a piece of metal, or the human body, the jar will be discharged. Both in charging and discharging a jar,



light will be observed, and this is called the electric spark.

When a large Leyden jar is employed, or any number of jars connected together are charged, electricity of great intensity is obtained, and it has a wonderful power in the production of heat. This fact may be easily proved by experiment; but great care should be taken, as the electricity might endanger life, if, instead of entering the substance intended, it should find a passage through the body of the individual thus engaged in research. If a large Leyden jar be taken, and charged, and the electricity be made to pass through two or three inches of very thin wire, that, for instance, which is called the watch pendulum wire, the wire, if the fluid have the required intensity, will be raised to a red heat, and even fused. Many feet have been melted, in this manner, in a single discharge, by uniting several large jars, and thus forming what is called an electric battery. In this instance heat is not produced by the presence of a bad conductor, for the metals have the power of transmitting electricity in a remarkable manner, but from having to pass through a substance too small to give the fluid a ready passage.

Another method of exhibiting the heating effects of electricity may be mentioned. Two small pieces of window glass, about three inches long and an inch and a half wide, may be taken, and a portion of gold leaf placed between them, these glasses being enclosed in a press, so as to keep them in close contact, and prevent the gold leaf from being driven away; a large Leyden jar then may be so discharged that the electricity must pass through the gold leaf, and it will not only be melted, but the heat will be sufficient to drive it into, or cause it to unite with the glass, staining it of a purple colour. The presses for this purpose are sold by philosophical instrument makers; but, in performing the experiment, care is necessary, as the glass is always broken into fragments by the mechanical force.

It was long since proved that lightning is an electrical effect, the discharge, in fact, of accumulated electricity. The vivid light we have observed may be occasioned by the passage of the fluid from one cloud to another, or from the clouds to the earth. In the latter case there is a stream of electricity passing from the one to the other, and its path is marked by a bright and broken line of light. The violent effects of electricity, in large quantities and with great intensity, are known by experiments made with electrical batteries, which consist of only a few feet of coated glass;

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STORM IN THE PYRENEES.

what then may we expect from the discharge of thousands of acres of electrified cloud? Men and animals are killed, houses are set on fire, and some countries are, in a few moments, desolated by it. When a house or any combustible substance lies in its path towards the earth, great damage is the usual result, and frequently entire destruction. Bell wires are melted in the same manner as the pendulum wire already described; and, should wood be struck by the electric fluid, a blackened and charred line is left to exhibit its effect, if it be not absolutely destroyed.

It is still by no means unfrequent for persons who are out in a thunder-storm to seek for shelter under a tree; but the fact just mentioned shows their extreme peril. Many cases have occurred in which the tree has conducted the electricity to such as have hoped for security, and, in a moment, they have been numbered with the dead. The prudent course is to avoid whatever may conduct lightning.

Heathens were not regardless of the awful phenomena of nature. The ancient Romans gave to their chief deity, Jupiter, the name of Tonans, the "thunderer;" and the emperor Augustus devoted a temple to this idol, because of his deliverance from great danger. Travelling by night, the vehicle in which he was carried was scorched by lightning, and a slave that bore his torch was instantly killed. His sense of obligation calls for shame in others, who are never affected by interpositions of Providence. Be it ours to remember, daily and hourly, that "in God we live, and move, and have our being." Every moment we are dependent on him.

Safety consists not in escape
From dangers of a frightful shape;
An earthquake may be bid to spare
The man that 's strangled by a hair.

Nor let us fail to contemplate the lightning of heaven in its true character.

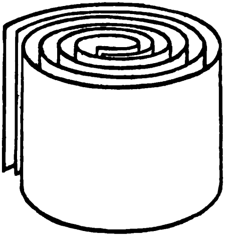
The same unchanging mercy rules
  When flaming ether glows,
As when it tunes the linnet's voice,
  Or blushes in the rose.

"The deep lowering of the thunder-cloud," says Mr. Whewell, "the overwhelming burst of the explosure—the flash from which the steadiest eye shrinks—and the irresistible arrow of the lightning, which no earthly substance can withstand, speak of something fearful, even independently of the personal danger which they may whisper. They convey, far more than any other appearance does, the idea of a superior and mighty power, manifest-ing displeasure and threatening punishment. Yet we find that this is not the language that they speak to the physical inquirer: he sees these formidable symptoms only as the means or the consequences of good. What office the thunderbolt and the whirlwind may have in the *moral* world, we cannot here discuss; but certainly he must speculate as far beyond the limits of philosophy as of true piety, who pretends to have learned that their work was more of evil than of good. In the *natural* world, these apparently destructive agents are, like all the other movements and appearances of the atmosphere, parts of a great scheme, of which every discoverable purpose is marked with beneficence as well as wisdom."

> Through nature's ever-varying scene,
> By different ways pursued,
> The one eternal end of Heaven
> Is universal good.

Would that the benevolence of God constantly attracted our attention, called forth our lofty admiration, enkindled our liveliest affections, and constrained us to delight ourselves in his service! Even as the thunder rolls through the sky, and the lightning casts its momentary glare over the face of nature, to the intelligent Christian there is a voice that whispers "God is love!"

To return, now, to the heating effects of electricity, which suggested these remarks, it may be observed, that they are peculiarly apparent in the galvanic or voltaic battery. This instrument is now formed in various ways, having been much improved during the last few years. It is usually made of the two metals, copper and zinc, with an acid solution. The simplest form is a series of discs, or round pieces of metal, with pieces of cloth moistened by diluted sulphuric or nitric acid between them. For some experiments, many pairs of plates, or alternations, to use the common scientific term, are required; but the heating effects depend on the amount of copper and zinc employed, and not on the number of pieces. A long piece of copper, for instance, and a piece of zinc of the same size, rolled up in the form shown in the figure, will make an excellent galvanic battery for heating effects, when plunged into a vessel of water, to which nitric or sulphuric acid has been added.



To exhibit the heating effects of voltaic electricity or galvanism, the wires connected with the zinc and copper ends of the battery may be connected, as in the figure, by a piece of watch pendulum wire, and this will instantly be red-hot. Another method is to moisten the end of one wire, and taking up a piece of gold or silver leaf to bring it to the wire connected with the opposite end of the battery, a rapid combustion of the metal instantly follows, and a bright light will be given out, varying in colour according to the metal employed. In a similar manner, combustible bodies may be fired, and many interesting experiments, which will be at once suggested to the reader, may be performed.

The origin of the heating power exhibited by electricity is by no means thoroughly understood. Some scientific men believe it to belong to the fluid by virtue of its own nature ; but others imagine, with more reason, that the effect is occasioned by a mechanical force—a sudden compression of the particles of the body through which it passes.

Combustion, to which a passing allusion may be made, is an instance of the production of heat by a chemical change, but this point we must hereafter notice. In concluding this chapter, it may be remarked that the word "heat," and others expressive of its modifications, are often used in Scripture, either as metaphors or emblems, to denote various states and conditions of man, and even some of the attributes of the Deity. Its expansive and energetic character peculiarly fits it for these representations. Christians are exhorted to be "fervent in spirit, serving the Lord;" and their love is said to "wax cold" when they decline in religious affection. When David was "musing, the fire burned; then spake" he with his "tongue," or recorded with his pen, those strains of devotion which have enkindled the ardour of the church in past ages, and still remain to animate ours. When the Almighty appeared to Moses in the plains of Midian, it was in "a burning bush;" and when he gave the law on Mount Sinai, "he descended upon it in fire." The same emblem is expressive of the holiness and justice of God; and, as the avenger of wickedness, he is styled "a consuming fire." At the descent of the Judge of all, "the elements shall melt with fervent heat," and the finally impenitent will be doomed to suffer "the vengeance of eternal fire." The influence of the Holy Spirit in sanctifying the heart, and animating the Christian in his course, is also described as a flame of holy energy; and our blessed Lord is compared, by the prophet Malachi, to "a refiner's fire;" by which it appears to be intimated, that He shall purify those who believe on him and love him, by his doctrine and his grace, while he shall consume the wicked by his judgments.

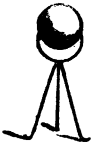
In considering these impressive descriptions, let us remember, that "the wrath of God is revealed from heaven against all ungodliness and unrighteousness of men." The thoughts from which he is shut out, the feelings which violate his law, and the actions which do not aim at his glory, are alike condemned. *We*, then, are exposed to the Divine indignation. It behoves, therefore, every one to say: "How can I flee from the wrath to come?" The gospel of Christ supplies the answer to this all-important inquiry: it exhibits Him who is able to save to the uttermost, demands the exercise of a simple and entire confidence in the only Redeemer, and secures, in so doing, the richest blessings for time and eternity.

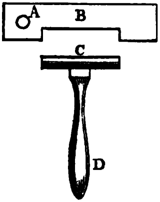
CHAPTER IV.

EXPANSION OF SOLIDS—MEASUREMENT OF HEAT—THE PYROMETER—COMPENSATING PENDULUMS—EXPANSION OF LIQUIDS—ICE—A WISE AND BENEFICENT PROVISION AS TO FREEZING.

THE attention already given to the nature of heat, and to the sources whence it is derived, has prepared the way for considering some of its effects. One of these is expansion—a rapid augmentation of bulk. This effect is so common, that it may be daily, almost hourly, observed in the common process adopted in cooking, and in other domestic operations equally familiar. And from these we may proceed to very different circumstances. Some of the most striking phenomena of nature, as well as of the most remarkable mechanical contrivances, are founded on the same universal law; and without a knowledge of it, and the extent of its influence, many, if not all systems of machinery, would be constantly disarranged. Nor is its effect confined to a particular class of substances; for solids, liquids, and gases, all expand upon an increase of temperature, and contract proportionally in cooling.

The expansion of solids may be easily proved experimentally, but it is difficult to measure with accuracy its amount. If a metal ring, through which a ball will scarcely pass when cold, be made red-hot, it will expand so much, that the ball will drop through almost without touching. The reverse of this is a still more striking experiment; and in the figure, a method is shown of fully exhibiting it. The apparatus consists of a wire frame, in the form of a cup, just large enough to receive an iron ball when cold, the frame being supported on three legs, formed of stout iron wire. When it has been shown that the ball will pass through the iron rim, put it in a fire until it is red-hot; and then, if it be placed on the stand, it will rest on the rim, being so much expanded by heat that it will not pass through. In cooling, however, it contracts, and after a short period will drop as before into the frame.





There is another method, scarcely less striking, of showing the expansion of metals, which is represented in the annexed figure. B is a flat plate of brass, one edge of which has been cut out so as to receive a brass cylinder, C, which is fitted to a convenient handle, D, formed of a substance that does not conduct heat. A is a hole at one extremity, just large enough to receive the end of the cylinder; plunge the cylinder into boiling water, or put it into a clear fire, and the temperature will be raised, causing it to expand both in length and diameter, so that it will neither pass into the notch nor through the hole.

In many of the most common manufacturing processes, advantage is taken of the expansion of metals; and some few instances may be mentioned before an attempt is made to explain the methods of measuring the amount of expansion, and the more refined processes in which it is employed.

The wheels of carriages are surrounded by hoops of iron, called the tires, which fit so closely that the pieces of wood composing the circular rim, and called the felloes, are bound to the spokes. The construction of wheels is, therefore, in a great measure dependent on the tightness with which the iron binds them; it is consequently found necessary to heat the hoop, so that it may expand, and it then binds closely on cooling, preventing the work from falling apart, which it would do if it were not thus strengthened. In constructing barrels, tubs, and other vessels intended to contain liquids, the same provision is necessary, and is commonly adopted. The knowledge of this method of binding the several parts of vessels formed of wood, enables the artizan to accomplish his objects with a less amount of labour, and consequently at a smaller cost than would otherwise arise; and, at the same time, to give strength and security not to be obtained by other means.

The cracking of glasses when hot water is poured into them, is another instance of expansion from heat. Tumblers, and all glass vessels employed for domestic purpose, are so made as to be of unequal thickness in the several parts; the bottoms are always the thickest; and even the sides vary in substance, the upper parts being the thinnest. When hot water is poured into a vessel, the solid matter immediately begins to act as a conductor, and expansion is the result; but the expansion is not equal throughout at the same moment, and consequently the glass is broken. Other articles formed of the same substance, are liable to similar accidents; the plates of electrical machines, for instance, when placed before the fire so as to be suddenly warmed, often crack, as window glasses do, when there is a sudden change of temperature from heat to cold.

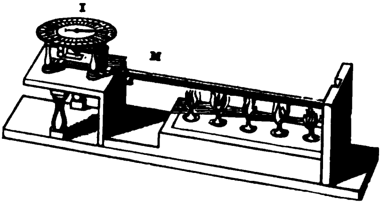
From the present use of iron as a substitute for timber, in various parts of buildings, mechanics have become fully aware of the necessity for making due allowance for its expansion and contraction, so that these changes may occur without injury being done to other parts of the building. Where iron beams are used, for example, they are so placed as to admit of some play without mischief to the walls; and where this has not been done, their expansion or contraction has endangered the whole building. Iron roofs, from their exposure to the influence of the hot sun, or to the cold of winter, require peculiar care in this respect; and in other cases, apparently of trivial importance, very serious consequences have resulted from the incautious use of iron bars. In some instances danger will arise, as it did to the fine steeple of Bow Church, in Cheapside. The stones of the building were held together by clamps, or bars of iron, with their ends bent into them, and the expansion of the metal in summer forced the stones sufficiently apart for dust, or sandy particles, to lodge between them. When winter came, the stones, not being at liberty to close as before, the contraction caused the ends of the shortened clamps to be drawn out, and the effect increasing from year to year, endangered the whole structure.

The reader has probably passed over the Southwark bridge. It is made of iron, and has three arches having a large span. Now, within the usual range of atmospheric temperature, these rise and fall about one inch each; if, then, attention had not been given, by the engineer, to the fact now under consideration, the consequences would have been very serious.

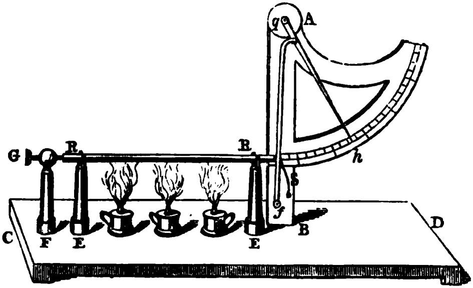
To measure the expansibility of solids is by no means an easy task. The first difficulty in an attempt to invent an instrument for the measurement of expansion, arises from the extreme minuteness of the increase. By the mere observation of a solid during its increase in temperature, the expansion could never have been known; and it is only by such results as may be accidentally presented to notice, that an intelligent observer could even guess its occurrence.

It must, at the same time, be remembered, that a solid will expand equally in every direction, and therefore its figure is not in any degree changed. If a bar of lead be raised in temperature to the boiling point of water, and have an expansion in length equal to a three hundred and fiftieth part of its length at the freezing point, it will have a similar expansion of breadth and thickness. But to measure the amount of expansion in the solid would be extremely difficult, and therefore instruments are so formed as to estimate it in one direction, that is to say, in the length.

The first attempt to construct an instrument for the measurement of the expansion of solids, was made by the celebrated Musschenbroek. The one which he invented was called a pyrometer; and by the same name other mechanical contrivances, having a similar object, are known. The instrument by which he proposed to measure the expansion of metals, is represented in the figure. A metallic bar, M, was made to act upon a system of wheels, so constructed that the slightest expansion of the metal would be shown on a large scale by the index, I. By a suitable and accurate adjustment of wheels and pinions, the amount of expansion in steel, iron, brass, copper, and lead, was determined by him with considerable accuracy. To describe the precise mechanical contrivance which he adopted is not at all necessary. The delicacy of this instrument was much increased by the adoption of cylindrical rods, and certain mechanical improvements by Desaguliers.



It is not desirable that a description should be given of all the inventions by which the linear expansion of solids may be measured. There is, however, one so admirably suited for the exhibition of the fact, that metals expand by an increase of temperature, and that all metals have not the same amount of expansion with an equal increase of temperature, that it deserves some notice. This instrument is here represented. A B is an upright of wood, fastened to



a board, C, D. To the former is attached a quadrant, having on the face a scale of equal parts. To a central pivot, *q*, is attached a moveable hand, *q h*, which is so connected, by a lever, with a thin steel bar, *q f*, that the slightest motion is greatly magnified, the steel bar itself being supported by a spring S. E E are metal uprights, mounted to receive the rod, R R, the expansion of which is to be determined. The upright, F, is used to carry the screw, G, by which the rod is adjusted.

If, then, a number of bars be taken, formed of different metals, but of precisely the same length; and if it be required to determine the lineal expansion of any one of these, let it be fixed in its place, and the screw, G, advanced against one end, until the opposite end presses gently against the bar, *q f*, the arm, *q h*, being in a vertical position. Some lamps should then be placed under the rod, to raise its temperature: expansion follows, the arm is raised, as shown in the diagram, and the degrees of the expansion may be read off on the quadrant.

From what has been stated, it must be evident that the metals, and to these may be added glass, and some other solid substances, expand by an increase of temperature. Tables have been formed, showing the difference of dilatation between the various metals, and, from an examination of these, a general law is deduced, that the most fusible metals are also the most expansible. This is not, perhaps, strictly true;

but it is so near the truth, that those who have occasion to employ metals in the construction of new machines or philosophical contrivances, find it of great service to them in making their calculations.

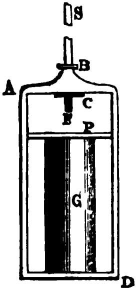
Instances of applying the expansibility of metals have been already noticed, to which many others might have been added; but it is desirable to illustrate the importance of the principle by reference to some equally valuable and more philosophical contrivance. The following may, therefore, be mentioned. The walls of a gallery in the Conservatoire des Arts et Matiers, in Paris, were, some years since, much bent from the perpendicular by the weight of the roof and other causes. To restore them to their original upright position was much desired, and M. Molard undertook to do this, by an ingenious application of the expansive power of metals. Having made, in the opposite walls, a number of holes, he introduced a series of metallic bars, and fastened them on each side by plates, all the bars being parallel to the end walls, and perpendicular to the walls which were to be brought to the upright. The temperature of the bars was then raised by the application of heat, and, when they had expanded, the plates were advanced, that is to say, the nuts which secured them were screwed up. On cooling, contraction followed, and the walls were, to the amount of the contraction, drawn up. By repeating this process, the walls were ultimately brought to their perpendicular position, and remain, to the present day, secured by the bars, which extend across the building.

The importance of a knowledge of the expansion of metals by heat, is also exhibited in an interesting manner in the construction of compensating pendulums. A brief account of their use, and the means by which the expansion to which they are subject is corrected, may be with propriety introduced.

A pendulum is a heavy body attached to a thread or wire, so suspended that it may vibrate on a point. It is principally employed for regulating the rate of going in clocks, and its mathematical and mechanical principles are now so well known, that time may be kept by a good clock with almost inconceivable accuracy. Upon the length of the pendulum depends the going of the clock, for its oscillatory motion, as its movement backwards and forwards is called, is increased or decreased as its length is changed. That a pendulum may beat seconds in London, it must be 39.13929 inches long; if it be longer than this its motion will be slower; if shorter, it will be faster. Thus, for instance, if the ball, or as it is technically called, the bob of a common pendulum, attached to a clock, and beating seconds be lowered only one hundreth part of an inch, the clock will lose ten seconds in every twenty-four hours.

Now, the variation of temperature is sufficient to cause a great alteration in the length of the pendulum, and thus derange the going of the clock. To prevent this error, the pendulum must be so made that the expansion shall be neutralized. Many methods of doing this have been proposed, one or two of which may be noticed.

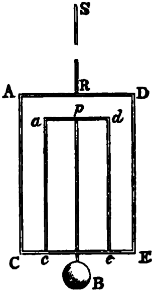
The first compensation pendulum appears to have been made by Graham, who, in the year 1715, made many experiments on the expansion of various metals, hoping to succeed in applying two or more of these solids in such a manner as should secure the formation of an instrument that could not vary its motion by an alteration of temperature. But he soon discovered, that the difference of expansion in metals was so small, that he had no hope of accomplishing his first intention. Yet his investigations were not without value, for they led him to the invention of the mercurial pendulum, in 1721. The following figure represents this ingenious and admirable contrivance, with the improvements which have been introduced in modern times, and as recommended by Mr. Bailey in his valuable paper on pendulums, in the "Transactions of the Astronomical Society of London." S F is a rod, or bar of steel, attached to the frame, A D, formed of the same metal by the screws, B, C. G is a glass vessel containing mercury, and covered by a metallic plate, P. Now, the increase of temperature which causes the metallic rod to expand downwards, acts upon the mercury, and produces an expansion upward. Thus these two motions are made to neutralize each other, so that the centre of motion is kept without change.



Captain Kater proposed the use of a rod of glass. "Its cheapness and simplicity," he says, "much recommend it. It is merely a cylinder of glass, of about seven inches in depth, and two inches and a half in diameter, terminated by a long neck, which forms the rod of the pendulum, the whole blown in one piece.

"We have unquestionable authority for saying, that the mercurial pendulum of the usual construction, that is, with a steel rod and glass cylinder, is not affected simultaneously in all its parts by a change of temperature. Now, the pendulum of which we are treating, being formed throughout of the same material in a single piece, and of the same thickness in every part, cannot expand in a linear direction, until the temperature has penetrated to the whole interior surface of the glass, when it is rapidly diffused through the mass of mercury. M. Biot mentions, that a pendulum of this kind was formerly used in France, and expresses his surprise that it was no longer employed, as he had heard it very highly spoken of. The writer has also used a pendulum with a glass rod, which differs from that just mentioned in having the lower end of the rod firmly fixed in a socket attached to the centre of a circular iron plate, on the circumference of which a screw is cut, which fits into a collar of iron, supporting the cylinder (to which it is cemented) by means of a circular lip."

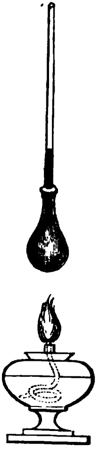
Another method of compensating for the expansion of metals, was proposed by Harrison, originally a carpenter at Barton, in Lincolnshire, who was induced, by hearing of Graham's suggestion, to give his attention to the subject. In 1726, he produced an instrument, formed of parallel rods of brass and steel, called the gridiron pendulum. The principle of this instrument may be explained by the figure. Let S R be the rod of the pendulum, and S the point of suspension. A C D E, is a



metallic frame attached to the pendulum rod, and *a c d e*, another frame, to which the rod *p*, is attached, carrying the bob B. Now, supposing all these rods to be fixed one to the other, no very evident advantage could be the result; but let it be supposed that the inner frame, *c a d e*, is attached to the bottom, C E, of the larger frame, and let the rod, *p*, pass through, and be capable of motion in a hole of the same bar; then, as all the parts of the pendulum may be expanded by heat, there will be two distinct and opposite motions. The rod S R, and the outer frame, A C D E will expand downward, but the inner frame will expand upward. A metal must therefore be chosen with such an amount of expansion, and be placed under such circumstances, that the expansion upward may prevent any change in the centre of oscillation by the expansion downward. The pendulum is formed in various ways, and many improvements have been made since its invention; but it is not necessary to explain these, as the notice here taken of the instrument is only intended to show the application of the expansion of metals by heat.

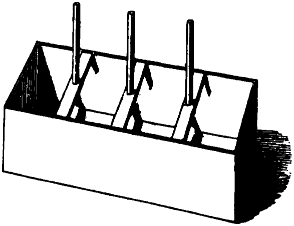
All fluids, whether liquids or gases, expand with an increase of temperature, but there are differences of results which require a distinct notice.

The mere fact of the expansion of a liquid by heat may be shown, in a striking manner, by the following experiment. Take a long glass tube, at one end of which a bulb has been blown; and having filled the bulb with coloured water, so that the liquid may rise about half an inch in the tube, place it on a stand over the flame of a spirit-lamp, or dip it into boiling water, and the liquid will instantly begin to rise in the tube. The experiment may be still more strikingly performed by using a Florence flask, into which a tube has been fastened, as shown in the figure. The effect will be sufficiently evident if water be used; but the amount of expansion will be greater by the use of spirits of wine.



All liquids have not the same degree of expansion with the same increase of temperature; a fact which might have appeared probable from the alteration of bulk in solids, but has also been proved in reference to liquids, as well as solids; for it is found that, as those of the latter class which are easiest fused expand most, so those of the former which boil at the lowest temperature are the most expansible.

That the expansive powers of liquids are various, may be proved experimentally by an instrument here represented. A tin vessel is provided, with a false bottom, in which as many circular holes are cut out as there are liquids to be compared, for these will be necessary to support the bulbs which are to contain the fluids. To the end of some tubes, bulbs may be easily blown. Fill all the tubes to a certain height with the liquids, and, placing each bulb in the hole provided to receive it, slip over the tube a small piece of tin, as shown in the diagram, to support it in a perpendicular position. Then pour into the vessel boiling water, and the height to which the several liquids rise in the tubes will be their relative degrees of expansion. If a greater degree of accuracy be desirable, place the tin vessel on a stand, and a spirit lamp beneath it, so as to keep the water at the boiling point. The three liquids best suited for experiment are mercury, water, and spirits of wine.



It is also worthy of notice, that an equal increase of temperature does not produce an equal expansion, even in the same liquid. This fact may be shown by a very simple experiment. There are, however, other methods of proving it, and of ascertaining, with more accuracy, the precise amount of expansion, for every relative increase of temperature, from the freezing to the boiling point. Take a tube and bulb, as already described, and mark the height of the liquid, when first introduced. Then place it over a spirit lamp, or any other source of heat, and observe the expansion after equal intervals of time, as, for instance, a minute or five minutes. Between every successive interval of time the expansion will be greater: thus it will be more during the second than the first, and the third than the second, and so on, until it boils. This result is accounted for by the supposition, that the cohesive power resists the expansion, and that, as the cohesion becomes less, the expansion becomes greater. That this explanation may be thoroughly understood, a few general remarks may be found useful.

Cohesion is that force by which the particles of matter are held together. That the particles of a solid are more closely bound together than those of a liquid, and the particles of a liquid than those of a gas, would have had a bed of ice, increasing with the continuance of the cold, till the whole was frozen. On their surface there could only be such pools of water as could be produced by the thawing of the summer sun, and these would be congealed again on the return of frost. And so the process would advance, till all the water of these reservoirs became ice. Such a change would be fearful indeed; how, then, can the evils of it be averted?

God who enacted the law, to which reference has just been made, has modified it for our existence and welfare. As cold increases, water contracts, but after a certain diminution of temperature, though there is a further increase of cold, so far from contracting, it actually expands till it reaches the point at which it becomes ice. The greatest density of water is at forty degrees, and when at or near this point, it will lie at the bottom with cooler water, or with ice floating above it. The cooling process may go on at the surface, but water colder than forty degrees cannot descend to displace water that is warmer. At the bottom of deep water, ice, therefore, can never be formed. The coldest water, in approaching the freezing point, rises to the surface; there ice is formed, and there it will remain till the air and the sun restore it to its fluid state. Every

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ICEBERGS.

winter we have some proof of this in the ice that floats for a time on our ponds, lakes, and rivers. What, then, must be the evidence afforded in the polar regions, on which the eye of the poet was fixed when he said:

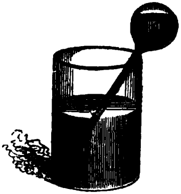
> ———————————— The muse
> Then sweeps the howling margin of the main;
> Where, undissolving, from the first of time,
> Snows swell on snows amazing to the sky;
> And icy mountains, high on mountains piled,
> Seen to the shivering sailors, from afar,
> Shapeless and white, an atmosphere of clouds.
> Projected huge, and horrid, o'er the surge,
> Alps frown on Alps; or, rushing hideous down,
> As if old Chaos was again returned,
> Wide rend the deep, and shake the solid pole.
> Ocean itself no longer can resist
> The blinding fury; but, in all its rage
> Of tempest taken by the boundless frost,
> Is many a fathom to the bottom chain'd.

Ice-bergs are islands of frozen water, considerably elevated, generally perpendicular on one side, and sloping gradually down on the other. They are sometimes two hundred feet in height. Floating ice has about one seventh of its thickness above water; but ice-bergs are sometimes aground, and therefore show a greater proportion of their height. They are formed either by the pressure of large masses of ice upon each other by winds and currents; or are detached by their own weight, or the action of waves, from the vast glaciers which abound in Greenland and Spitzbergen. It is to be observed, that sea-water requires a lower temperature, by three degrees and a half of Fahrenheit, to freeze, than is necessary for common water. Man often employs rafts for his safety and convenience, but here the Arctic bear sometimes takes his stand; and, doubtless, to his surprise, is left to the wide ocean, as the ice-berg melts beneath him. The masses of ice which have been frozen together, gradually separate as summer advances, and clear spaces of water are left, but these begin again to be frozen over as early as the end of September. When, then, we look on ice in the water of our own land, or on representations of it on the mighty deep, let us remember that here a law operates without which the whole economy of the material world would be disarranged. Thus as we trace the operation of natural causes, we find that a knowledge of God's works, even in the inanimate world, affords new sources of gratitude; nor can we sufficiently adore his wisdom and love who has so amply provided for the existence and comfort of feeling and thinking beings.

CHAPTER V.

EXPANSION OF AËRIFORM BODIES—SIMPLE AND BEAUTIFUL PROVISION—VENTILATION—THE WINDS—THE SIMOOM—THE MONSOON.

In considering the expansive power of heat, it is not enough to refer to it as operating on solids and liquids, it acts also on all gases or aëriform bodies: this may be easily proved by experiment. Take a tube, having a bulb, and partly filling it with water, invert it in a jar containing the same liquid, as shown in the figure. The upper portion of the bulb will then contain a bubble of air. Under this, bring a spirit-lamp, and the air will immediately expand, and this to so great an extent, that after a short period, all the liquid will be driven from the tube, and even a portion of the air itself may be expelled. To give another instance: let a piece of lighted paper be thrown into a glass goblet, and allowed to burn in it.



If, then, the goblet be immediately inverted, and its mouth immersed in a basin of water, the water will be observed to rise in the goblet above the level of that in the basin. The cause of this is, that the flame of the paper produced an expansion of the air in the goblet, and on inverting the glass, the rarefied air was inclosed above the water, and separated from the air around. But on the paper being extinguished, the temperature of the air was reduced to that of the water in contact with it; it therefore contracted, and the pressure of the atmosphere acting on the surface of the water in the basin, forced a quantity of the water into the goblet to fill the space left by the contraction of the air.

When bottled porter or ale is placed before a fire, the heat will cause the particles of air combined with the liquid to expand, and rise into the space of the neck of the bottle between the liquid and the cork. This process will be continued until a considerable quantity of condensed air is collected under the cork; the elastic pressure of this is increased by the elevated temperature; and it often happens, that this pressure so much exceeds that of the external atmosphere, that the cork will be driven out from the bottle with a noise like that of a gun.

The same fact may be shown in another manner. Take a small bladder, and pressing out of it the greater portion of the air, tie up the mouth, so that no air can pass either in or out. Having done this, the bladder being previously moistened, may be placed before the fire, or boiling water may be poured on it, and the expansion of the air will become evident from the inflation of the bladder, which will be quite filled by a rarefied atmosphere.

It may be well to remark, that the expansion of air may also arise from another cause, the diminution of pressure. Thus, if the bladder mentioned in the last experiment be placed under the receiver of an air-pump, and the air in the receiver be exhausted, that in the bladder will expand, because it bears a less pressure. Even if weights to the amount of twelve or thirteen pounds be placed upon it, they will be raised, so great is the force of expansion.

Having thus far examined the effect of heat on solids, liquids, and vapours, in causing them to expand, it may be desirable to point out the difference between the expansion of a gas and that of solids and liquids. When gases are said to dilate and contract by variations of temperature, it is necessary to attend to the fact, that this process does not take place in the same manner as in liquids or solids. When a solid or a liquid is cooled, the repulsive principle arising from the presence of heat being diminished, and the resistance to cohesion being lessened, the particles are collected more closely together by the operation of the cohesive principle, and the body, whether solid or liquid, contracts and shrinks into smaller dimensions. This, however, does not happen in the same manner with bodies in the aëriform state.

Suppose a glass receiver filled with air, and completely closed on every side; if the temperature of the air thus included in the receiver be lowered, it will not cease to fill the receiver, nor will it contract in any respect in its dimensions. It will still continue to occupy the same space as before; it will, however, lose a portion of its elastic force, and exert a less pressure on the inner surface of the receiver, so that if the external pressure were allowed to act, it would be compressed into smaller dimensions. When it is said, therefore, that gases contract or expand by changes of temperature, it is meant, that the contraction or expansion takes place, the gas being subject throughout the process to a given pressure, which pressure is generally understood to be that of the atmosphere.

The expansibility of aëriform bodies is one of the wise provisions of the God of nature, and is a means of equalizing temperatures to a great degree. Imagine, for a moment, that the atmosphere had not this property, and that in equatorial regions the air resting on the heated earth did not rise in consequence of its lightness, not only would a large portion of the earth be incapable of supporting life, but an impassable ocean of intensely heated air would separate one hemisphere from the other.

Air emitted from the lungs has lost its purity by being breathed, and hence that of crowded rooms is unpleasant and injurious. If, then, the corruption of the atmosphere by the respiration of innumerable animals be considered, together with its deterioration by other means, incalculable evils appear to impend over the human race. But these are averted by the simple but beautiful law, so constantly apparent, of the lightness of heated air.

The expansion of air by heat, and the consequent production of currents in the atmosphere, the heated parts of it rising, the colder descending, is a means of carrying away the deleterious gases, which are by various causes disengaged, refreshing the earth with supplies of oxygen, and giving life, vigour, and enjoyment to all animated creatures. To what part soever of the field of experimental research we turn, these convincing proofs of the boundless wisdom of God are presented, so that we ought ever to be ready to exclaim with the psalmist, "O Lord, how great are thy works! All thy works praise thee, O Lord!"

The comfort of man greatly depends on ventilation.

We have often observed small tin ventilators, consisting of a rotatory wheel, placed in window-frames; but latterly they appear diminished in number. Their use had better be entirely discontinued; for though it is imagined, in consequence of their apparent activity, that they must be very effectual, they are utterly useless: the fact is, they are set in motion by a very trifling current of air; their movement may be occasioned alike by air going out and by entering; and the apertures for the escape of air are so small, as to produce no sensible effect on that of the apartment.

The art of ventilating rooms and buildings, is chiefly dependent on the currents produced in the air by changes of temperature. As the heated air and effluvia of crowded edifices pass upwards, apertures are usually left in or near the ceiling for their escape: such an opening, however, though it allows the foul air to escape from its specific lightness, is also apt to admit a counter current of denser and colder air pouring down into the building, and producing great inconvenience. But if the tube or flue, through which the foul air escapes, be heated in any convenient way, this effect is prevented. A current, constantly rising, is thus established; and whenever cold air attempts to descend, the heat of the flue rarifies and drives it upwards.

It will be desirable now to examine the laws of nature under consideration on a larger scale; here we rise to some of the most impressive phenomena. Wind is nothing but air, in sensible motion; or, in other words, winds are currents in the atmosphere, occasioned by various causes, but chiefly by variations in temperature. It should be remembered, that air is elastic, or capable of compression and expansion. This elasticity is increased by heat, which rarefies and expands the air, and wind is the necessary consequence; for when the atmosphere is heated over one part of the earth more than over another, the warmer air, being rarefied, becomes specifically lighter than the rest; and being thus raised, diffuses itself over the upper parts of the atmosphere, while the neighbouring air rushes in from all parts at the bottom, and thus continues to produce one or more currents till the equilibrium is restored. Whatever, therefore, destroys the equal temperature of the air in any part, produces in that part a wind of greater or less violence, according to the degree of rarefaction, or the increase of elastic power.

Seneca defines wind to be air flowing; and he illustrates this by saying, that a current of air is to the atmosphere during a calm, what a river is to a lake. Nothing is wanted to complete the accuracy of this definition, so far as the effect is concerned. But Seneca, though he refutes and exposes some erroneous attempts to explain this phenomenon, and asserts that the air has the power of contracting and expanding itself, yet seems not clearly to have seen that this contraction and expansion were caused by the agency of heat alone. To include the effect and the cause in the same definition, wind may be defined, A current of air moving in one direction to restore the equilibrium, which has been broken by the rarefaction caused by the excess of heat in another; or, in the words of Professor Playfair, "The disturbance of the equilibrium of the atmosphere by the unequal distribution of heat."

A remarkable effect, to which the wind contributes, occurs in all the mouths of the Ganges, particularly in the Hooghly, at spring tides. The time of its approach being well known, hundreds of boats may be seen rowing as for life, towards the middle of the river, the crews urging on each other with wild shouts or shrieks, though at the moment no danger appears. But the spectator soon feels the precaution necessary; for the *bore*, as it is called, foams by with tremendous noise and velocity.

The following table will give some idea of the variations of the wind, in different circumstances.

at.

THE WINDS.

Miles per hour.	Character of wind.
1	..... Scarcely perceptible.
2 or 3	..... Just perceptible.
4 or 5	..... Gently pleasant.
10 to 15	..... Pleasant, brisk.
20 to 25	..... Very brisk.
30 to 35	..... High wind.
40 to 45	..... Very high wind.
50	..... Storm, or tempest.
60	..... Great storm.
80	..... Hurricane.
100	..... Ditto, that tears up trees, and carries buildings before it.

The last is seldom or never experienced beyond the tropical regions; but the highest of the other rates have been noted by persons who have ascended in air-balloons. The variations of velocity, indeed, are very great, from the gentlest breeze to the wildest hurricane.

It appears, from a register kept by order of the Royal Society, that, in and near London, the south-west wind blows, on an average, more frequently than any other wind, during every month of the year; and that it blows longest in July and August: that the north-east blows most constantly during January, March, April, May, and June, and most seldom during February, July, September, and December; and that the north-east wind blows oftener from November to March, and more seldom during September and October, than any other months.

The most violent and destructive wind that was ever known in England, was on the 27th of November, 1703; it commenced three days before it arrived at its height. A strong west wind set in about the middle of the month, the force of which was increased every day till the 27th. Great damage was sustained, and much alarm excited, both by sea and land. The late Rev. Dr. Stennett, in endeavouring to account for it, observes that, having most probably taken its rise in America, it made its way across the Western Ocean, and, collecting confederate matter in its passage over the seas, spent its fury on those parts of the world whither this army of terrors was principally commissioned. The violence of the wind produced a hoarse dreadful noise, like one continued peal of thunder, whilst the excessive darkness of the night added to the horror of the scene. Some accounts say that it lightened; but it is probable that this apprehension arose from there being, at times, many meteors and vapours in the air, the hurry and agitation of nature being too great to admit of thunder and lightning in their usual course.

Great loss of property was sustained, many painful accidents happened to those who escaped with their lives; and not a few had all their apprehensions realized, as they met death in some of its most dreadful forms.

In the city of London and its vicinity, more than eight hundred dwelling-houses were laid in ruins, and above two thousand stacks of chimneys were precipitated to the ground.

As a further proof of its strength and fury, we are informed, that the lead which covered the roofs of one hundred churches was rolled up, and hurled, in prodigious quantities, to great distances. The dreadful devastation spread throughout the country. In one extensive plain on the banks of the Severn, not less than fifteen thousand sheep, being unable to resist its violence, were driven into the river, and drowned. So great was the number of trees torn up by their roots, that a person, anxious to ascertain it, had proceeded through but a part of Kent, when, arriving at the prodigious amount of two hundred and fifty thousand, he relinquished the undertaking!

The cause of these effects may be easily understood; let oil be placed under water, and it will be pressed up to the surface, and swim there: just so does the air near the surface of the earth, heated by the action of the sun, rise to the top of the atmosphere, and spread there, being forced up by the heavier air around. Here is the origin of wind—it is the heavier air rushing inwards. Were the earth at rest, and the rays of the sun always falling on the same part, the earth and the air directly under that luminary would become very hot, and the air would constantly rise like smoke from a great fire, while there would be currents or winds in all directions below, towards the central spot. But from the motion of the earth round the sun, in order that we may have the seasons of the year, the middle region may be called the sun's place, and hence there is a constant rising of air over it, and constant currents from the north and south to supply the ascent. This is the origin of the winds of the northern and southern hemisphere, called trade-winds, on which, in most places within thirty degrees of the equator, mariners reckon almost as certainly as on the rising and setting of the sun.

But these winds do not seem to be directly north and south, though really so, because the daily rotation of the earth on its own axis, causes a wind from the north to appear as coming from the north-east, and a wind from the south, as coming from the south-east. Dr. Arnott happily illustrates this by the case of a man on a galloping horse, to whom a calm appears to be a strong wind in his face; and if he be riding eastward, in a directly north or south wind, this will appear to him to come from the north-east, or south-east. Or again, if a small globe be made to turn on a perpendicular axis, and a ball or some water be allowed to run from the top of it downwards, the ball or water will not immediately acquire the whirling motion of the globe, but will fall, almost directly, downwards; and if the track be marked upon the globe, it will appear not as a direct line from the axis to the equator, or from north to south, but as a line falling obliquely from north-east to south-west, if the globe be turning from west to east, like our earth. It is thus the whirling of the earth is the cause of the oblique and westward direction of the trade winds, and not, as has often been said, the sun drawing them after him. We have, then, on the north side of the equator, a north-east, and on the south side, a south-east wind, gradually declining towards the east as we approach the equator. This is called the trade wind, and is the most considerable and extensive instance of irregularity. Further irregularity is produced by a great diversity of causes: one of them in particular appears in the variety apparent in different parts of the earth's surface for acquiring and communicating heat. During the day the land is more heated than the sea; therefore, in all the islands of the torrid zone, the wind is, during the day, blowing in every direction towards the centre of the land. When the sun goes down, the land is more rapidly cooled than the sea by radiation, and the direction of the wind is changed: thus the breeze is from the land to the sea, and is called the land breeze.

Mr. Clare exemplifies this by the following experiment:—

"In the middle of a vessel of water, place a water-plate of warm water, the water in the vessel representing the ocean, and the plate the island, rarefying the air above it. Then hold a lighted candle over the cold water, and blow it out, and the smoke will move towards the plate. But if the plate be filled with cold water, and the fluid in the vessel be warm, the smoke will move in a contrary direction."

If we advance near a marsh, or enter a wood, in warm weather, a cool breeze proceeding from them seems to welcome our approach. The air which has been cooled by evaporation in one case, and by a shade, impervious to the sun's rays, in the other, is in motion to restore the balance, which has been disturbed by the greater warmth of the surrounding atmosphere, or that which is extended round the wood or the marsh. A little before sunrise, the air sometimes, as if awakened by the near approach of the sun, rises in a gentle breeze, and advances to salute him. This is occasioned by the greater warmth of the region which has already felt the influence of his rays. The ancient naturalists were misled by a reluctance to suppose that a change of temperature, which they confessed had some share in the production of wind, was adequate to occasion those terrible effects which they beheld in a storm. But the progress we have made in discovery, has taught us that, if two solutions of any phenomenon are proposed, for which the arguments are equally balanced, we ought to prefer that which is most simple, and least imposing.

To the wind there are many references in the sacred Scriptures. How sublime, for instance, is the language of the psalmist! " They that go down to the sea in ships, that do business in great waters; these see the works of the Lord, and his wonders in the deep. For he commandeth, and raiseth the stormy wind, which lifteth up the waves thereof. They mount up to the heaven, they go down again to the depths: their soul is melted because of trouble. They reel to and fro, and stagger like a drunken man, and are at their wit's end. Then they cry unto the Lord in their trouble, and he bringeth them out of their distresses. He maketh the storm a calm, so that the waves thereof are still. Then are they glad because they be quiet; so he bringeth them unto their desired haven. Oh that men would praise the Lord for his goodness, and for his wonderful works to the children of men!" Psa. cvii. 23—31. Our Lord said to Nicodemus: "The wind bloweth where it listeth, and thou hearest the sound thereof, but canst not tell whence it cometh, and whither it goeth; so is every one that is born of the Spirit," John iii. 8. How interesting and all-important is this declaration! The wind blows from different parts of the compass, and more gently or furiously, and men are unable to direct its course or to stay its effects. Much respecting it, too, remains utterly unknown. Who, then, can understand how the Spirit of God acts on the soul? We observe a new course; but the power that bends the will, and renews the heart, escapes all observation. Nor is it under human control. "Every good gift and every perfect gift is from above, and cometh down from the Father of lights, with whom is no variableness, neither shadow of turning," James i. 17. Here, then, is an unerring guide. To whom can we go but to Him, if we feel our deep necessity? to whom are our praises due, if we have already received from His fulness?

Winds give rise to phenomena not yet noticed. Mr. Barrow, speaking of land-storms, remarks :—"They are sometimes attended with tornados that are really dreadful. Wagons are overturned, men and horses thrown down, and the shrubs torn out of the ground; the dust and sand are whirled into the air in columns of several hundred feet in height, which, at a distance, look like water-spouts seen sometimes at sea, and with those they are equally, if possible, avoided; all that falls in their way being snatched up in their vortex. Sometimes dust and small pebbles are hurled into the air with the noise and violence of a sky-rocket: rain and thunder generally succeed these heated winds, and gradually bring about a decrease of temperature."

The following account of a very extraordinary cloud of sand, which appeared near the Orange river, was given by the Rev. Mr. Melville, to a friend, from a journal he kept when residing near Phillipolis: it is dated on the 6th of January, 1830.

"Clouds of dust, resembling a thick fog, are not uncommon in this country; but I had never witnessed any so remarkable as the one I saw to-day. It came on from the southward, and was, probably, raised by a storm of wind near the Orange river, which lies about sixteen miles in that direction from Phillipolis.

Being accustomed to see clouds of dust in that quarter, at a distance, this was not particularly noticed; but, as it drew nearer, its singular and grand appearance attracted the attention even of the Hottentots. It was about a thousand feet in altitude, and extended nearly four miles in breadth. The dust having a reddish hue, and being brilliantly tinged by the sun, while this glowing colour was strongly contrasted with the gloomy blackness of those parts in shade, I was forcibly reminded of descriptions I had read respecting the vast volumes of fire and smoke that proceed from a volcanic eruption. Although it was known to consist only of dust, it rolled on towards us with a terrific grandeur that was calculated to strike the beholder with sensations of awe and wonder. When it first reached us, at about five o'clock in the afternoon, it merely resembled a thick mist; but, quickly increasing in density, it became impenetrable to the light of the sun, and surrounded us with midnight darkness. Standing in the open air, I could only discover objects at the distance of ten yards. Within the houses, persons could not see each other, it being as dark as in a closed room at night, with the lights extinguished. The Hottentots, who were sitting in their huts, were immersed in total obscurity, and many persons were filled with violent fears. The thickest darkness did not last beyond a quarter of an hour, but the cloud of dust did not pass over in less than an hour and a half."

Among the inconveniences and dangers to which the traveller in Arabia is exposed, none is perhaps more dreaded than the simoom, or hurricane. Nor can we be surprised at the terror that is manifested; horses must not only be placed under shelter, but have their heads covered and their ears stopped, lest they should be suffocated by the whirlwinds of fine and subtle sand which the wind sweeps furiously before it. Men assemble under their tents, stopping up every crevice with extreme caution; and having provided themselves with water placed within reach, throw themselves on the ground, covering their heads with a mantle, and stir no more till the desolating hurricane has passed.

Providence has given the camel an instinctive sentiment for its preservation. It is sensible, two or three hours beforehand of the approach of this scourge of the desert, and turning its face away from the wind, buries itself in the sand; and neither force nor want can move it from its position, either to eat or drink, while the tempest lasts, though it should be for several days.

It must, indeed, defy description; for furious gusts of wind are succeeded by clouds of red and burning sands, whirling round with fierce impetuosity, and overthrowing or burying under their drifted mountains whatever they encounter. If any part of the body is exposed to its touch, the flesh smells as if a red-hot iron had been passed over it. The water from which refreshment is expected, is quite hot; and the temperature of a tent in which Lamartine was, exceeded that of a Turkish bath. And when, at length, he and his party ventured from their tents, a dreadful spectacle awaited them; five children, two women, and a man, were extended dead on the still burning sand, and several Bedouins had their faces blackened and entirely calcined, as if by the action of an ardent furnace. When any one is struck on the head by the simoom, the blood flows in torrents from his mouth and nostrils, his face swells and turns black, and he soon dies of suffocation.

It would, however, be partial and unjust to consider the winds only as ministers of evil, and agents of calamity; they are much more frequently the causes of benefit than of injury, and some of our most important blessings are procured by their means. When we think of storms and tempests, we should think also of the influence of the wind in promoting commerce and navigation, which, without its aid, could never be pursued to any great extent. The occasional destruction of life and property, through its violent action, should remind us of its perpetual use in purifying the atmosphere, and rendering the earth itself both fertile and healthy.

One proof of this may be added to these statements. At the commencement of the monsoon in India, there is an incessant pouring of rain, amidst constant peals of thunder, and flashes of the most vivid lightning, attended with violent blasts of wind. This lasts for some days, after which there is a striking contrast to the previous state of the earth: before the storm, the fields were parched up, and except in the beds of the rivers, scarce a blade of vegetation was visible; no cloud interrupted the clearness of the sky, but the atmosphere was loaded with dust. Nor was this a slight inconvenience, for the dust was so great as to render distant objects dim as in a mist, and even to make the sun appear dull and discoloured till he attained a considerable elevation. A parching wind blows, moreover, like a blast from a furnace, and heats wood, iron, and every solid material even in the shade. But when the first violence of the storm is past, the whole earth is covered with a sudden yet luxuriant verdure; the rivers are full and tranquil—the air is pure and delicious—the sky is varied and embellished with clouds.

Here we may pause, after quoting the words of a poet:

Ye viewless minstrels of the sky!
I marvel not in times gone by
  That ye were deified:
For, even in this later day,
To me oft has your power or play,
  Unearthly thoughts supplied.

Awful your power! when by your might
You heave the wild waves, crested white,
  Like mountains in your wrath;
Ploughing between them valleys deep,
Which, to the seaman roused from sleep,
  Yawn like death's opening path.

Graceful your play! when round the bower,
Where beauty culls spring's loveliest flower,
  To wreath her dark locks there;
Your gentlest whispers lightly breathe
The leaves between, flit round the wreath,
  And stir her silken hair.

Still, thoughts like these are but of earth,
And you can give far loftier birth:
  Ye come!—we know not whence;
Ye go!—can mortals trace your flight?
All imperceptible to sight,
  Though audible to sense.

The sun—his rise and set we know;
The sea—we mark its ebb and flow;
  The moon—her wax and wane:
The stars—man knows their courses well;
The comet's vagrant path can tell;
  But you his search disdain.

Ye restless, homeless, shapeless things!
Who mock all our imaginings,
  Like spirits in a dream;
What epithet can words supply,
Unto the bard, who talks so high,
  Unmanageable theme?

But one;—to me, when fancy stirs
My thoughts, ye seem *Heaven's messengers*,
  Who leave no path untrod:
And when, as now, at midnight hour,
I hear your voice in all its power,
  It seems the *voice of God.*

CHAPTER VI.

EFFORTS TO MEASURE HEAT—THE THERMOMETER—DIFFICULTY AS TO INVENTORS AND DISCOVERERS—FAHRENHEIT'S, REAUMUR'S, AND THE CENTIGRADE THERMOMETER—THE ONLY STANDARD OF SENTIMENT AND CHARACTER.

IT must have been thought desirable to have some means of measuring heat from the period in which attention was first directed to this important agent. No invention, however, was made by the ancients, or, at least, no account of any has reached our own day, nor was it until the commencement of the seventeenth century that the principle of expansion was applied. It appears, therefore, that the ancients had no other means of measuring the variations of temperature than by the sense of touch, and observations upon the combustion, liquefaction, or other changes of substances. They had consequently no means of expressing more than a general relationship between the temperature in one instance and in another. Thus they might say "that substance is hot," or "very hot;" and if they wished to fix the height of temperature more exactly, they might say it is "as hot as boiling water." In this manner, it would be possible to convey to any person some knowledge of the relative temperatures of substances, and for ordinary purposes it would be found sufficient; but, to the man of science, such loose and indefinite statements would be of no value.

The instruments used by the modern philosopher, in his attempts to ascertain the temperature of bodies, are founded upon the amount of expansion, as already described, and are called thermometers, from the Greek words, *thermos*, heat, and *metron*, a measure. The methods of constructing them are various, depending partly on the purposes for which they are to be employed, and partly on the fancy of the person who orders or constructs them. The term thermometer, however, is confined to those instruments which are so formed as to measure temperatures by the expansion of liquids or gases. Those in which the same object is effected by the expansion of solids have been called, as we have already seen, pyrometers, from the Greek words *pur*, fire, *metron*, measure, and by way of distinction, the term may with advantage be retained. The use of these terms in connexion with their real signification, may not be either very evident or very accurate, and yet there is a difference in the common acceptation of terms, between the words heat and fire not inappropriately applied to these instruments. The thermometer determines the heat of a boiling liquid, but it is altogether unfit for the measurement of the heat of a fire or furnace, for which purpose a pyrometer must be employed.

It may be again necessary to caution the reader against the misapprehension of the phrase, "a measure of heat." When a thermometer is said to be a measurer of heat, it is not meant that it gives evidence of and absolutely measures all the heat contained in a substance to which it is applied, but only that which is sensible to the touch. That a substance contains more heat than is sensible, must be evident from the possibility of raising the temperature, which word has the same meaning as sensible heat, of iron by striking it, and of pieces of quartz or wood by rubbing them together.

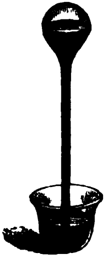
Many claims have been made for the honour of inventing the thermometer. There are, indeed, but few great scientific discoveries which can be with certainty ascribed to an individual so as to exclude, satisfactorily, the claim of any other person. This may, in part, be attributed to national vanity; for although science is much neglected by the people at large, and but few inducements of a pecuniary nature are offered for its pursuit, men are jealous of scientific honours; and after having neglected the inventor or discoverer, greedily appropriate to themselves the credit arising from the labour they had disregarded or contemned. But a still greater reason for this may be found in the gradual advance of scientific knowledge. Discoveries are not made by loose conjectures, or guesses as to the results of certain principles. There are periods when scientific knowledge is in such a state, that the minds of many are directed to the same object, and hence the same discovery is made by different persons at a distance from each other. Or a suggestion being made by several writers at the same time, they claim, or succeeding generations demand for them, some right to the invention itself.

Among all those who have presented a claim for the invention of the thermometer, there are but two who have sufficient pretensions to require a notice in these pages; the one is Santorio, an Italian, the other Drebbel, a Dutchman.

Santorio was, for some time, a physician, practising at Venice, and, afterwards, a professor at Padua. His claim to the invention of the thermometer has been supported by many of the older as well as modern writers on science. To him we are indebted for the discovery of the insensible perspiration of the animal body, from which circumstance, as well as his acknowledged talent and information, it is not improbable that he has a right to the merit of the discovery.

Cornelius Drebbel was a physician at Alkmaar, and was highly esteemed by his contemporaries as a man of great learning and invention. The instrument which he is supposed to have been the first to form, was precisely the same, in every respect, as that to which the name of Santorio was also given, and was made in the following manner.

A glass tube, with a bulb at one end and open at the other, was first heated, so as to drive out much of the atmospheric air by expansion. In this state the open end was introduced into a cup, containing some liquid, as shown in the figure. Here it was allowed to remain; and as the air cooled, and, consequently, contracted, the fluid rose in the tube, being driven upward by the pressure of the atmosphere. At some point the motion upward was resisted by the expansion of the enclosed air, and according to the height was the temperature. Now, supposing the hand,



or any other body, having a temperature greater than that of the atmosphere, to be brought to the bulb of this simple thermometer, heat would be communicated to the enclosed air, and expansion necessarily follow. Supposing the tube to be of equal diameter throughout, a scale of equal parts might be attached, and the relative degrees of temperature could be read off. Such instruments being used for measuring atmospheric temperatures are called, by some of the older writers, weather-glasses, but are now termed air thermometers. To this form of the thermometer there are two objections, the exposure of the liquid to the varying pressure of the air, and the want of uniformity in the scale. The newly invented thermometer immediately attracted the attention of scientific men, and of the Florentine academicians in particular, by whom the objections were at once perceived. In their attempt to form a scale, they were decidedly unsuccessful, but they greatly improved the instrument.

Fahrenheit, a native of Dantzic, who afterwards resided at Amsterdam, devoted himself to the construction of the thermometer, and in consequence gained so much notoriety, that he may almost be said to have supplied the north of Europe with the instrument. His own name, too, was so fully associated with the invention, that even to the present day it is given to the scale. Fahrenheit, however, was not destitute of scientific knowledge, nor a mere manufacturer; for to him we are indebted for the discovery of the fact, that the boiling points of liquids are changed by the increase or decrease of atmospheric pressure. This has been proved by observation on the temperature of boiling water on mountains, but may be more easily shown by placing a little water, several degrees below the boiling point, under the receiver of an air-pump, and as the exhaustion proceeds, ebullition will be observed, and the water will boil violently. In Fahrenheit's scale, the freezing point of water is at 32°, and the boiling at 212°.

Reaumur's scale assumes the freezing and boiling points of water as fixed; but the former is registered as 0, and the interval between one and the other is divided into 80°, all temperatures below that of melting ice are therefore minus.

The centigrade scale was proposed by Celsius, a Swedish astronomer, and only differs from Reaumur's in having the interval between the freezing and boiling points divided into 100 instead of 80 degrees.

Here, however, it will be well to remember, that another standard is necessary to our welfare—a standard of sentiment and character. And where shall this be found? Assuredly not in the opinions and practices of men. The multitude, unhappily, do evil, and perfection has not been attained by any of the truly good. It is for us then to take for our guide the word of the God of truth; our appeal should be to "the law and the testimony;" and while it is so, in the humble and devout supplication of the aid of the Holy Spirit, we shall have light in the understanding, peace in the conscience, joy in the heart, and consistency in the life.

CHAPTER VII.

CONDUCTION OF HEAT—COVERING OF INFERIOR ANIMALS—DRESS OF THE ARCTIC TRIBES—THE BOILING OF WATER.

HEAT is communicated from one body to another in two ways; these are seen in nature, and adopted in art, and are called radiation and conduction. Conduction occurs from contact, and it will only be required to consider separately the effects on solids, liquids, or gases, because a substance which is an excellent conductor as a solid, may be destitute of the same power when in a fluid state.

Various non-conductors of heat must have attracted the notice of the reader. Some persons have strongly recommended the use of silk, particularly for under-clothing in winter, because it prevents the escape of heat from the system, and is said to render the feeling of health as buoyant and exhilarating amidst the fogs of November, as it is in the bracing atmosphere of a spring day. Furnaces are lined with fire-bricks, or covered with a coating of clay and sand, to prevent a waste of heat. Silver tea and coffee pots are made with handles of wood or ivory, as non-conductors, that they may be used conveniently: were they of metal, the hand would not be able, from the rapidity of conduction, to endure the heat.

Persons have sometimes occasioned surprise by placing a vessel of boiling water, just taken from the fire, on the palm of the hand. And how was it they did so with impunity? Because they were first sure that the bottom of the vessel was well covered with soot: this is a porous form of charcoal, one of the very worst conductors of heat, and thus they sustained no injury. Asbestos is also a very remarkable non-conducting substance; if some be taken in the hand, an inflammable body may burn there without injury to the individual. The Chevalier Aldini of Milan has employed it as a defence against fire: he has shown that a finger first enveloped with asbestos, and then in a double case of wire-gauze, might be held a long time in the flame of a spirit-lamp or candle, before the heat became inconvenient. One of his assistants, having his hand within a double asbestos glove, and his arm protected by a piece of asbestos cloth, seized with impunity a large piece of red-hot iron, carried it deliberately to the distance of one hundred and fifty feet, inflamed straw with it, and brought it back again to the furnace.

To prove that substances have different powers of conduction, the following simple and easily performed experiments may be made by the reader. Take a small rod or cylinder of iron, and another of wood, precisely similar as to size and form; round the wood wrap a piece of writing paper, as tightly as possible, and then bring the paper into the flame of a candle or spirit lamp, and it will be scorched, and, if allowed to remain long enough, will be inflamed. Now repeat the experiment with a piece of iron, or, indeed, any metal. Wrap the paper round it in the same manner, taking care that the air be excluded between the metal and the paper, and introduce it into the flame. The same effect will probably be expected in this, as in the former case; but on examining the paper no mark nor appearance of burning will be observed. To what cause are these different results to be traced? To the conducting powers of the two bodies. Wood is a bad conductor of heat, and, consequently, that received from the candle is, if we may so speak, concentrated upon the spot where it is thrown, and, augmented by continued application, is sufficiently intense to ignite the paper. The same amount of heat is communicated to the iron, but the metal being a good conductor it is not concentrated in the same manner, but is rapidly carried from particle to particle, so that it would be a long time after exposure to the source of heat that the paper would be burned.

Again, dip into boiling water rods of different substances, such as iron, wood, charcoal, earthenware, glass, and any other bodies whose relative conducting power may be required. When they have remained in the water for a few minutes they may severally be touched with the hand, and, according to their relative temperatures will be their relative conducting powers, some being so hot as to be uncomfortable to the touch, and others scarcely raised above the temperature of the atmosphere at the time.

It may be stated, as a general rule, which has some exceptions, that the substances which have the greatest density, have also the greatest conducting power. The metals, as already stated, are the best conductors, and next in order to these, stones, earthenware, and glass. The following are a few metals, arranged in the order of their conducting powers, as determined by Dr. Ure:—Silver, copper, brass, iron and tin, cast iron, zinc, lead.

In the arts it is often necessary to employ substances which have particular properties, and it is to aid the workman and manufacturer that such lists as the foregoing are prepared. Suppose, for instance, that a worker in metals is required to form a vessel in which water, or any other liquid, can be boiled in the shortest possible time. Looking over the table of conducting powers, he would be led to the choice of silver, but as that is an expensive metal, and one which cannot be used in the manufacture of large articles, he would employ copper, which is acknowledged to be by far the best metal for the manufacture of all vessels which are to be exposed to the fire, and intended to contain a fluid or other substance during the operation of boiling. Thus, for instance, in making a tea-kettle, the first thing to be considered is a substance which will readily conduct the heat from the fire to the water; but it is equally as necessary to provide against the possibility of any injurious chemical effect between the metal and the substance to be boiled. This may happen, and it is from this liability when copper is employed, that the interior of vessels is always tinned, a process by which a superficial coating of that metal is left upon the surface of the copper.

Chantrey, the justly celebrated sculptor, has a large stove or oven for drying the moulds employed in his bronze castings; a thermometer suspended in it generally stands at about 300°. The workmen enter and remain in it for some minutes without much inconvenience, and a person wholly unused to such extreme heat may walk into and out of it with impunity; should there be, however, any attempt to remain, it generally occasions difficult breathing, and a painful sensation about the eyes, the skin remaining parched and dry. In such experiments, it is necessary to avoid the contact of any conductor of heat; a piece of metal, if touched, would inevitably burn the individual. A person once inadvertently entered this stove with his spectacles on, which, being mounted in silver, burned his face at the points where they came in contact.

The covering of inferior animals now demands our notice. The chilling influence of night and the cold winds of winter, require for life and comfort appropriate means of defence. Some creatures dwell, too, in regions of snow and ice, and how could they have been preserved in their several species, without their heat being sustained? Now, a garment, peculiarly formed, is the defence provided. There are many substances which would not have answered the purpose; but, for one striking example, let us look at the plumage of birds, always pleasing to the sight and the touch, often rich and splendid in its colour, yet always harmonizing in its most contrasted tints, and always an adequate and happy defence.

A fact, no less interesting, appears in the covering of quadrupeds, growing at a rate precisely adapted to the climate and the season, and supplying the loss occasioned by accident. In warm regions, the elephant and the monkey appear, but their dress is short and thin: in the temperate zones, its texture thickens; while, as the poles are approached, the guise, like that of the arctic bear, is shaggy and coarse. Animals, like the otter and the beaver, having to resist the cold of water as well as of air, have in their fur a special defence.

The dress of the Arctic tribes, and especially of the Esquimaux, is chiefly formed of furs. The gracious Providence which has adapted the covering of the lower animals to the rigour of the climate in which they roam, has thus provided for man an equal defence. In the islands, and among the hills of their icy regions, these people obtain a better covering than the skins of southern climates, or the flannels which we so highly prize. The musk-ox and the white bear, the rein-deer and the hare, have a furry garment, first for their own use, and then for that of those who capture them. The Esquimaux, in his snowy hut, with

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a degree of heat scarcely enough to raise the mercury to the freezing point, has quite sufficient warmth to promote his comfort, and to secure his sound and refreshing slumber.

The rein-deer furnishes another example. Nothing can exceed the closeness of the hair of this animal, nor its capabilities of affording a warm and durable clothing, proof against the severity of the coldest winter. Its texture is coarse and harsh, its colour various; and so impervious is the hide to cold, that a traveller clad in the skin of the rein-deer, with a blanket of the same material, may bivouac on the snow with safety all night during the most intense cold of the polar regions.

The reader will perhaps be prepared to hear, that liquids are most excellent conductors of heat, and yet the reverse is the fact. The common opinion is, without doubt, derived from the facility with which liquids are boiled in household utensils; but science has come to a conclusion so different, that it was long doubtful whether they conducted heat at all. To make this apparent difficulty quite intelligible, the effect produced on the water contained in a tea-kettle when placed on the fire shall be traced as a familiar example, bearing in mind the fact already stated, that liquids are bad conductors of heat.

As soon as heat is applied to the vessel, the metal of which it is formed begins to conduct it, but it instantly meets with a substance which has no conducting power. Yet although this is almost strictly true, it must be at the same time evident, that the particles of water in immediate contact with the heated solid must have a slight increase of temperature. These heated particles would give from mere contact a slight increase to those adjoining them, and thus one might act upon another over a range too minute for us to appreciate. This would happen if the particles of which water consists had fixed and determined places, and we should say of it that its conducting power was very small, and scarcely to be detected by the most delicate instrument. The particles of liquids are, however, not fixed, but have a great freedom of motion.

All liquids also expand when their temperatures are raised—a fact which is well illustrated by a common thermometer, the fluid of which rises and falls with the increase or diminution of heat to which it is exposed. But there is a consequence following from the expansion by heat which explains the secret of boiling liquids. When the particles are heated and expand, they become lighter than those by which they are surrounded, and, being lighter, they rise, and others sink to the bottom, to be in their turn heated; and thus there is a continued succession of particles rising and sinking, until the entire liquid is reduced to an uniform temperature, which can only be at the boiling point.

As the explanation now given of the cause of boiling depends on the fact, that bodies become lighter when they are expanded, an illustration of it may here be added. Fishes are provided with an air-bladder, which they can fill at pleasure. When the animal withdraws the air provided for this vessel, it has its greatest weight, and sinks; when it inflates the bladder, it becomes bigger and lighter, and floats or swims.

The management of a balloon is also illustrative of the same fact. When the aëronaut ascends on a fine sunny day, he soon discovers that the gas in his balloon is expanded by the heat, and that, if he does not allow some of it to escape, it will, by its own expansive force, burst the covering by which it is confined. He opens, therefore, a valve, and allows some of the gas to escape; but, instantly this is done, the balloon mounts up higher in the atmosphere, being lighter. His balloon is now as full as it was when it left the earth, but the gas is lighter, having expanded from heat.

CHAPTER VIII.

RADIATION OF HEAT—THE COAL-FIRE—REFLECTION OF HEAT—THE DIFFERENTIAL THERMOMETER—ABSORPTION OF HEAT—CHOICE OF CLOTHING—DEW.

It has just been seen, that heat may be communicated by conduction; in these instances the source of heat is in contact: but it is equally true, that heat may be communicated from one body to another at a distance, by a process called radiation; an example of which will probably convey to the mind a clearer impression than a definition.

Who hath not sat beside a glowing fire
  Some cheerless night, and watched the pageant there
Of cities bristled o'er with dome and spire,
  Red, as if glowing in the sunset glare;
Or marshal'd troops, that rank by rank expire,
  Or steel-clad knight, or lady gay and fair?
The huge world mimick'd! for its fair and great
Moulder to dust as surely, though more late.

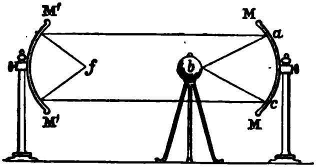
The heat received from a coal fire, when we stand before it, but at a considerable distance, is radiated.

Air is not a good conductor of heat, but is acted upon, when in contact, in the same manner as water;

the particles in close communication with the source of heat being raised in temperature, and expanding so as to have a less degree of density, and consequently to float. In all large rooms, in which many persons are congregated, the galleries and parts nearest to the ceiling are the hottest; for there are two currents of air, the heated air rising, the colder descending. To prove that there are two currents of air in every apartment heated by artificial means, let the following experiment be made: take a lighted taper, and hold it to the lower crevice of the door in any room which has a fire in it, and the flame will be blown inward, because cold air is rushing into the room; then place the light at the upper crevice, and the flame will be blown outward, for the heated air is lighter than the cold, and is passing away.

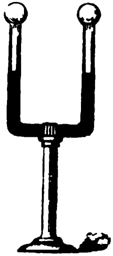
Now when a fire is lighted in a room, the air in immediate contact being made hotter, rises and gives place to another portion, which in its turn escapes. A part of the air thus heated may come into the room, and so far as that is concerned we receive heat by conduction; but the larger volume escapes up the chimney, so that the common sea-coal fire affords us warmth more by the principle of radiation than by conduction. There has on this subject been much discussion, many persons maintaining that the present method of warming buildings, or rather rooms, is a very bad one, and proposing to increase the temperature of the air by the communication of heat from iron pipes, in which hot water or steam is made to circulate. It is quite certain, that in English houses, little, if any, advantage is taken of the conduction of heat in warming apartments; but we are not quite sure that the plan adopted is so bad as many persons represent. That which is an imitation of nature ought not to be abandoned without sufficient reason, and that well demonstrated. How close an imitation the common coal-fire in our sitting-rooms is of the action of the sun, must be evident from what has been stated, for both are instances of the radiation of heat.

Every one is aware that light is reflected, and that in consequence of this he may see his own image in a looking-glass; but it is not so well known, that the rays of heat may, in the same manner, be turned from their onward course, and that the laws by which they are then governed are the same as influence light under similar conditions. Of all substances, the polished metals are the best reflectors of heat. For experimental purposes, concave discs of tin or zinc highly polished are, for the most part, employed; glass silvered is one of the best reflectors of light, but is much inferior to the metals in reference to heat. The late Professor Leslie, who was very successful in his experiments on this subject, endeavoured to determine the reflecting powers of several substances; and a few of these may be mentioned with their comparative powers:—Brass, 100; silver, 90; tinfoil, 85; block-tin, 80; steel, 70; lead, 60; glass, 10.



In the following figure is shown the form of the apparatus employed by lecturers and others to exhibit the reflection of radiant heat, and many curious and interesting phenomena resulting therefrom. Let M M, M′ M′, represent two mirrors, on wooden stands, *b* an iron ball, at a red heat. The rays of heat from the ball *b* are thrown around in every direction, and from every point of the surface. Many of these fall on the mirror, and are reflected in parallel lines. Two rays, *b a* and *b c*, are supposed to be radiated by the ball, and would pass off into space, becoming, at each point of their course, more distant from each other, that is, diverging. But these rays are stopped by the mirror, M M, by which they are reflected in lines parallel to each other, and would take this direction through space, were they not intercepted by another mirror, from which they are again reflected, but in a converging path. The point where they intersect each other, that is the point *f*, is called the focus, or fire-place, and there the power of all the rays is concentrated. When a large iron ball is used, and raised to a red or white heat, the degree of heat at the focus is intense, sufficient for the performance of many striking experiments.

The instrument commonly used to exhibit the passage of radiant heat, is called the differential thermometer, and was invented by the late Professor Leslie. It consists of a glass tube, in the form represented in the following diagram, supported in the centre on a stand, and terminated, at the two extremities, by large bulbs. Into this tube is poured coloured sulphuric acid, in a sufficient quantity to fill the horizontal tube and one arm. When the instrument is standing in any place where both bulbs are acted upon by equal degrees of heat, as, for instance, when they stand in a room with the same current of atmospheric air upon them, or, in other words, have equal temperatures, the fluid



will stand at the same height in both. But let one bulb receive an increase of temperature, and the fluid will immediately rise in the opposite one, by reason of the expansion of the enclosed air. The mere heat of the hand is sufficient to force the liquid from one tube to the other, so that the instrument is one of extreme delicacy, and admirably suited to the purpose for which it is used. To one arm a scale is attached, so that the relative effects obtained in two or more experiments may be measured: the bulb on this arm is called the focal ball, because it is the one on which the radiant heat is made to act, and it is coloured black, that a greater absorbing power may be thus obtained.

By using two mirrors, as shown in the figure on p. 113, the following experiments may be performed. Take a differential thermometer, and, placing it in the focus of a mirror, put before the opposite one an iron ball, previously heated in a furnace, and immediate evidence will be given of the communication of heat. This is an experiment which cannot be seen at any great distance. For public exhibition the following is more appropriate.

Instead of the differential thermometer, place a candle, and in the wick fix a piece of phosphorus, about the size of a peppercorn, and, if the ball before the opposite mirror be at a high temperature, the phosphorus will be soon inflamed, and the candle lighted. In a similar manner, any other body, which is combustible within certain ranges of temperature, may be inflamed. That it is the radiant heat by which the effect is produced, may be proved by placing a sheet of glass—and some other substances have the same power to intercept—between the body to be inflamed and its mirror, for the reflected rays are then stopped, and the combustion is not produced.

It is worthy of observation, that heat may traverse space in various lines, and undergo many physical changes, but unless it be absorbed by some body, we cannot be conscious of its existence, much less of its effects upon matter. When heat falls on any substance, it must be either reflected or absorbed: in the former case, it does not increase the temperature of the substance; in the latter it does. Hence, then, it may be supposed, that the best reflectors have little power of absorption; the metals, for instance, absorb heat slowly, being good reflectors, and especially when polished. But good radiators are also good absorbents of heat, for a substance must receive heat from some source before its radiation can be strikingly exhibited.

It is necessary in the construction of vessels required to contain liquids at a high temperature, to select one which is a bad radiator. But manufacturers are more guided by the public taste than the principles of science, and the public are, for the most part, governed by hasty conclusions and established prejudices. Females in the lower classes of society almost invariably use earthenware tea-pots, and commonly black ones, under the conviction that they "draw better" than the bright metallic ones. But that property which is called the drawing of a tea-pot, is, evidently, its power of confining the heat, and thus producing a stronger infusion of tea. In selecting a substance for this purpose, we should prefer one that had little radiating power; and as we know that a bright metallic surface, such as the Britannia-metal, of which tea-pots are frequently made, is a bad radiator, we select it, rejecting the black earthenware, which is so erroneously employed.

The radiation of heat should be considered in the choice of clothing. It has been discovered by the experiments of Franklin, Leslie, and other philosophers, that the dark colours absorb and radiate heat much better than the light ones, black possessing these properties in the greatest, and white in the least degree. It is well known to every one, as a common observation, that the heat received from a black dress, when exposed to the action of the sun, is very oppressive, while white and the lighter colours absorb but little, and are, consequently, cool. Hence it is that, during the summer, clothing of a light colour is used, while, in the winter, the darker is preferred.

It is, however, a matter of doubt whether black is the warmest wear in winter, for it is the colour which radiates best, as well as absorbs rapidly, so that it may carry away the heat of the body in a greater degree than it receives heat from the atmosphere, or the direct rays of the sun, which are then but feeble under the most favourable circumstances. But this balancing of properties, with regard to winter clothing, is not of much moment, as substances are chosen for other reasons, and especially their powers of conduction. To these instances of the application of the principles of radiation, reflection, and absorption, many others might be added, but sufficient have been stated to impress the fact upon the mind of the reader; and these remarks shall be closed by explaining one or two interesting natural phenomena, especially that called dew, which entirely depends on the laws stated in the preceding pages.

In the morning, after a cold night, a dampness or moisture may frequently be seen on the interior surface of the glass in a bed-room window. This is an appearance which must have been often observed by the least thoughtful of our readers, and even he may, perhaps, have asked himself, Whence comes all this moisture? as he wiped the window, to obtain a view of the accustomed scenes. No probable reason being immediately suggested to his mind, he has, at once, relinquished the inquiry, and has had so little interest in knowing, that he has not even thought it necessary to ask for information from some one who could have explained the cause. It is this indifference to common phenomena, and a want of interest in the causes of what is seen, that prevents, so frequently, the increase of knowledge. The reason for the deposition of moisture upon the bed-room window during a cold night, may be easily perceived.

The temperature of the atmosphere always falls, in some degree, after the sun has set. The atmosphere of the room, however, is not lowered to the same extent, but the coldness of the outer surface of the window-pane is communicated to the inner surface. Now, the atmosphere, at all times, contains some moisture in the form of vapour, which, coming in contact with the cold glass, is condensed, as a thick moisture, upon it. If the cold be very severe, the moisture will be frozen, and appear as a coating of ice upon the pane.

To understand this more fully, and to be satisfied that the cause assigned is the real one, an interesting and very simple experiment may be performed. On a frosty night, a little before or soon after sunset, take two small pieces of tin-foil, and paste one upon the outside of a pane, and the other upon the inside of another pane. When the windows are examined on the following morning, the part of the inner surface of the glass opposite to the outer piece of tin-foil will be quite, or almost free from ice, while all the other parts will be covered, and, especially the inner tin-foil. These different effects are easily explained on the principle of radiation. During the night radiation goes on from all substances, even the articles of furniture in a bed-room become colder and colder, from this cause. There is, therefore, a kind of mutual action between all substances which radiate and absorb heat; the interior of the apartment, for instance, radiates its heat to external objects, and absorbs the heat radiated by the same. Now, in this mutual action, the temperature of the internal air is lowered. Bearing these facts in memory, it will be easy to account for the effects already mentioned.

The piece of tin-foil on the exterior of the glass prevents the radiation of the heat outwards, for the metal is a good reflector, and radiates but little, if at all. The temperature of the glass which it covers is not, therefore, so much lowered as the other parts of the pane, and, consequently, ice is not formed. If the glass were a conductor of heat, the temperature would be almost instantly equalized, and the ice would be produced on all parts equally. The tin-foil on the interior does not prevent the radiation of the heat of the glass outward, while it does entirely prevent the absorption of radiant heat from the interior of the room, so that the temperature of the part it covers is lower than any other. These interesting experiments may be varied greatly, and even devices may be formed by the frost, if the tin-foil be cut out in proper shapes.

In a similar manner, the phenomenon of dew may be explained. There are but few persons who have not had an opportunity of witnessing this beautiful appearance; and yet there are some, who, confined in large cities from their infancy, have never wandered in early morning along the sheltered paths of bedewed hedges and fields, and indeed have but a confused notion of what is meant by dew. There are many, however, who have from their birth been surrounded by natural objects, and who would smile at the ignorance of those who have not witnessed the phenomenon so familiar to them, to whom facts well known to the man of science would be equally novel. They know that vegetation is frequently covered with drops of water, which glitter under the rays of the rising sun, and have perhaps enjoyed the freshness of the morning air when all nature has been invigorated by this gentle deposition of moisture, but they are probably ignorant that dew is not formed when the night is cloudy, or under the shadow of trees; and much less are they acquainted with the cause of its production—these facts we will endeavour to explain.

Dew is occasioned by the condensation of the vapour of the atmosphere upon bodies which are good radiators of heat. It is an effect in every respect analogous to the deposition of moisture on the inside of a window pane during the night. After the sun has set, the radiation of heat lowers the temperature of the ground and of all vegetation; and the aqueous vapour contained in the atmosphere is deposited in the form of dew. This, however, can only occur when the atmosphere is free from clouds; for if the heavens be overcast, there is a mutual radiation between the earth and the clouds, so that there is an absorption of heat as well as a radiation, and the temperature is not sufficiently lowered to cause the condensation of the vapour.

Dew is not formed on all substances, nor upon the same substances under all conditions; the grass and trees may be loaded with condensed moisture, but the vegetation which has been protected by spreading branches has not on it the least moisture. The cause which protects the entire surface of vegetation during a cloudy night, prevents the formation of dew under the shade of a tree, that is to say, mutual radiation. The tree radiates heat as well as the ground which it shades, so that the temperature is not sufficiently lowered to condense the vapour of the atmosphere.

That dew is not formed on all substances, must be evident from the fact, that all substances do not radiate heat, and therefore are not cooled in the same degree as those which possess the property. This is what would be expected from a knowledge of the facts mentioned in the former pages, but it is easy to prove the truth of the statement by experiment:—Take a piece of polished metal and a piece of glass, and place them side by side on a grass plot when the dew is falling, if we may use a common expression, but more properly when radiation is going on. The glass will soon be covered with dew, but on the metal not a single globule will be observed; the glass is a good radiator, and is therefore cooled rapidly; the metal radiates but little, and therefore retains its temperature.

There are many other circumstances as to the formation of dew, for which it is easy to account by an acquaintance with the properties of radiation, reflection, and absorption; and there are also many natural appearances which depend on the same qualities in bodies, for which a satisfactory reason may be given; such as the production of clouds and mists, in all their varieties of condition and form. To some of these allusion must be made hereafter.

Many are the references in the Scripture to the dew, which from its plenteousness in warm countries, and in places where rain is seldom granted, serves, in some degree, to supply its want. Thus we read of Joseph, "Blessed of the Lord be his land for the dew," Deut. xxxiii. 13; while the withholding of it was considered a curse; "Ye mountains of Gilboa, let there be no dew upon you," 2 Sam. i. 21. "My speech," said Moses, "shall distil as the dew," Deut. xxxii. 2; thus showing that the truths he announced were designed to operate on the heart as the dew does on the earth. The "goodness" of the ancient people of God, in the days of Hosea, was compared to "the early dew," which goeth away, Hos. vi. 4. And how rich are the blessings secured them in the days of their penitence by the promise, "I will be as the dew unto Israel: he shall grow as the lily, and cast forth his roots as Lebanon. His branches shall spread, and his beauty shall be as the olive-tree, and his smell as Lebanon. They that dwell under his shadow shall return; they shall revive as the corn, and grow as the vine: the scent thereof shall be as the wine of Lebanon," Hos. xiv. 5—7. Soon may that gracious declaration receive its entire fulfilment, and the Jews be brought into the fold of Christ with the fulness of the Gentiles!

CHAPTER IX.

THE DISCOVERY OF LATENT HEAT — PROCESS OF FREEZING — FREEZING MIXTURES—SINGULAR EFFECTS OF EXTREME COLD.

HEAT is not always sensible to the touch, nor does it always give evidence of its presence by affecting the thermometer. A piece of metal, for example, weighing a pound, may have a certain sensible heat or temperature, but an ounce of the same metal will affect the thermometer in an equal degree. It cannot however, be supposed, that the ounce of metal has heat to the same amount as the piece which weighs a pound. Much heat, also, is received by substances when changing their states from solids to liquids, and from liquids to vapours, which is altogether inappreciable to the thermometer. The presence of the heat may be proved without a doubt, but it cannot be measured by expansion or by the touch. It is, therefore, in this state, said to be latent.

The discovery of latent heat is universally ascribed to Dr. Black; and it may be doubted if any one fact has done more than this towards a just view of the operation of natural causes. To trace his investigations in the order in which he pursued them, is not, in the present instance, either desirable or proper; but, having paid this just tribute to the memory of a philosopher of no ordinary capacity of mind, and the friend of the illustrious Watt, a general and popular view of his discoveries, and those which have resulted from the facts he developed, will be better suited to the present purpose.

Bring into a warm room, in any convenient vessel, some snow or ice, and in it fix a thermometer. Should the temperature be lower than the freezing point, the mercury will soon rise to that point, receiving heat from the atmosphere into which the consolidated water is brought. Supposing, then, the snow or ice to have a temperature of 32° Fahrenheit, what effect will be produced before the thermometer shows that the vessel and its contents have the temperature of the atmosphere in the room? The first effect is the melting of the ice; but, during the whole period occupied in this process, the thermometer gives no evidence of the increase of temperature; but the moment that the liquefaction is completed, the mercury begins to rise, and continues gradually to do so, until the water has the same temperature as the atmosphere of the apartment in which the experiment is made. These are not, in all probability, the effects which would be anticipated by a person who, for the first time, considered the subject without reference to experiment. But, having ascertained that there is no increase of sensible heat, during liquefaction, what opinion is to be formed of the cause? It is certain that heat must be received; and it can only be supposed that it is so applied by the substance as to be the cause of a change of state, from that of a solid to that of a liquid. Heat thus applied is said to be latent, or, to use a still more appropriate term, it is the constituent heat. This supposition is supported by other experiments of a more delicate character, and the assumption fully explains phenomena which could not otherwise be accounted for by any known law of nature.

Another equally simple experiment may be made, proving that heat may be received by bodies, without increasing their temperature, and that the heat so received becomes a constituent part of a new state of the same particles of matter. When 'a saucepan or kettle, containing water, is placed on the fire, it is allowed to remain until the water boils, and is then removed. Now, the vessel is not removed because the water is hot enough, but because it cannot be made hotter; and this is a fact easily proved by introducing the bulb of a thermometer into the liquid; for if the vessel be allowed to remain on the fire, and a great heat be communicated, the temperature will not be in the slightest degree raised. But steam is formed; and all the heat communicated to the water after it is raised to the boiling point, is engaged in the production of vapour.

To ascertain the degree of heat required for the liquefaction of a solid, or the vaporization of a liquid, is not so difficult a task as may, at first, appear; for a tolerably accurate approach to the truth may be made by very simple means. Thus, for instance, by comparing the length of time required to raise a given weight of water one degree of temperature, with the time necessary for the liquefaction of the same weight of ice, the amount of heat received will be known.

Dr. Black performed an experiment which was well suited to ascertain the amount of heat which must become latent for the liquefaction of ice. Having obtained two globular glass vessels, of the same size and weight, he placed in each five ounces of water. The liquid in one of these was frozen by immersion in a mixture of snow and salt, and that in the other was reduced to a temperature of 33°, one degree above the freezing point. These two vessels were placed in a large hall, under precisely the same circumstances, or as nearly so as could be obtained. In each of the vessels a thermometer was placed, and the effects were observed separately. In about half an hour the thermometer in the water indicated a temperature of 40° Fahrenheit, that is to say, it had risen seven degrees. When the vessel containing the ice was taken from the freezing mixture, it was four or five degrees below the freezing point. The temperature, however, rapidly rose, and the time was noted when the thermometer stood at 32°; after an interval of ten hours and a half, a very small spongy piece of ice remained unmelted on the surface of the water. In a few minutes more, the whole of the liquid was raised to a temperature of 40°, the same as the water in the previous experiment.

From this interesting investigation much may be learned. An increase of temperature, equal to 7° Fahrenheit, was given to water in half an hour. Ten hours and a half, or twenty-one half-hours were required to melt ice, and raise the water to the same temperature; or, let it be assumed, that twenty half-hours are required to melt the ice, the remaining half-hour giving the increased temperature. The amount of heat received during the liquefaction was, probably, the same as that of which the thermometer gave evidence in the experiment with water, namely 7° Fahrenheit; so that 7 into 20, equal to 140, will be the amount of heat, in degrees, received by the ice, in a change of state—that is, in becoming a liquid.

All liquids, with one exception, alcohol, may be reduced to a solid state; and as it can scarcely be supposed that this substance differs from all others in so important a condition, scientific men are generally of opinion, that it also will become solid when a sufficiently low temperature can be obtained. All solids, also, may be converted into liquids by heat; for since the experimentalist has been in possession of the voltaic battery and oxy-hydrogen blowpipe, the most refractory substances have been overcome, and all have been reduced to a fluid state. The terms employed in expressing the change from one condition to the other are so well understood as to require but little, if any explanation. When a solid becomes fluid, it is said to be melted or liquefied; when a substance which is liquid at common temperatures becomes a solid, it is said to be frozen. These terms are applicable to all circumstances, so that, whenever a solid takes the fluid state, it may be said to be melted or liquefied, and, when the opposite phenomenon occurs, the liquid may be said to be frozen, and this without reference to the temperature at which it happens.

Ice is invariably liquefied at a temperature of 32°, but water is not always frozen at the same temperature. Dr. Dalton succeeded in lowering the temperature of water to 5° of Fahrenheit, before it froze; but this can only be done by great care, and especially by preventing the slightest degree of agitation, or the presence of any solid particle, either of which would cause the immediate solidification.

The solidification of water, or freezing, is generally supposed to be a species of crystallization: when the process commences, beautifully delicate crystals, or spiculæ, may be seen darting through the water, and becoming more and more thickly combined together, until the whole mass or its surface is brought into a solid state. There are some substances, which in the act of solidification, assume a decidedly crystallized structure, and there are others which do not: there are also some which expand at the moment of congelation, and others which have a continued diminution of bulk as their temperature is lowered, and at the instant of freezing.

Water, as stated in another page, expands when it passes from the liquid to the solid state, and the expansive power is very great. The Florentine academicians, to test the force with which water expands in freezing, filled a strong brass ball with water, and closed the aperture with a screw. When the water was frozen, the globe was broken; and according to the calculations that were made, a force equal to about 28,000 pounds was required to produce this effect.

An interesting experiment is sometimes made with a saturated solution of sulphate of soda, to show the expansion of bodies in freezing. Take a glass flask, and fill it with a saturated solution of the sulphate of soda when nearly boiling. Let the mouth of the flask be closed, so as to exclude the atmospheric air, which, for the experiment to be made, will be best done by tying round it a piece of wet bladder well strained. As the liquid cools, it will contract, so that when it reaches the temperature of the atmosphere, there will be little of the fluid in the neck of the flask, and the height may be marked by tying a string round the glass at the place where the level is formed. By applying the hand to the outside of the flask it will be evident that the temperature is about that of the atmosphere at the time. An interesting and peculiarly instructive experiment may now be performed; make a small opening in the bladder by pricking it with a large pin or otherwise, so as to admit the air, and crystallization will probably immediately commence on the surface, and proceed downward, until the whole of the fluid assumes the solid state. It is pleasing to watch the gradual but rapid solidification; but it sometimes happens, that the solution does not freeze upon the admission of the air, in which case a fragment of the same salt must be dropped into it, and radiating crystals will almost instantly spring from it, and the whole mass will in a very short time be solidified. On examining the flask, it will be observed that the surface of the few drops of liquid which still remain, is much above the string which marked the surface before crystallization.

It has been supposed, that the pressure of the air is in this experiment necessary for the solidification of the fluid; but as the liquid is not always frozen when the air is admitted, it seems probable that some other cause may be discovered. According to the opinion of many excellent writers, the freezing of the liquid is due to the presence of a solid particle, carried into the fluid by the air; and this is the more probable, since the introduction of a small crystal of the salt seems to form the nucleus for the crystallization of the whole mass which is then rapidly effected.

But there is another result which equally deserves attention: the flask, which had before a temperature not exceeding that of the atmosphere, will now be quite warm. This effect is easily explained by reference to the doctrine of latent heat. Before a solid can assume the liquid state, it must receive, as already explained, a certain amount of heat to be applied as a constituent part. When this liquid is reconverted into a solid, that heat must be again given out, and become sensible, so that the heat which is felt is the latent heat, or constituent caloric, of the fluid set free, and prepared to show its ordinary property of affecting the sense of touch.

It will, perhaps, be at once suggested to the mind of the reader, that it would be possible to ascertain the degree of heat required in liquefaction, by the degree of heat given out in solidification. Dr. Thomson adopted this principle in one way, and it is a process, at once so ingenious and so instructive, that it may be desirable to give his experiment, and its explanation, in the words of a popular author, who has stated the fact with as much clearness as is perhaps possible.

"If a vessel of water be carefully covered, kept free from agitation, and exposed to a temperature of 22°, it will gradually fall to that temperature, still remaining in the liquid state; but if a tremulous motion be communicated to it, or a particle of ice or other solid substance dropped into it, its temperature will suddenly rise to 32°, and a portion of it will be converted into ice. The cause of this singular effect is easily explained; a portion of the liquid which is suddenly solidified, gives out a quantity of heat, which is in part communicated to the water which still remains liquid, and raises it from 22° to 32°, and the remainder of it becomes sensible, instead of being latent in the ice itself, and likewise raises its temperature to 32°. In conformity with what has been already explained, it would follow that the latent heat thus extracted, would be sufficient to raise as much water as is equal in weight to the ice which has been formed through 140°; or it would raise fourteen times that quantity of water through 10° of the thermometric scale. Now, in the present case, the whole quantity of water in the vessel, including the frozen portion, has, in fact, been raised 10°; and it would follow from this reasoning, that the frozen portion should constitute the fourteenth part of the whole mass.

"The idea of applying this ingenious experimental test to the theory of latent heat, seems to have first occurred to Dr. Thomson, who has ascertained experimentally that, when water, being cooled without congelation to 22°, was suddenly agitated, the portion which congealed was one fourteenth of the whole quantity. He found, likewise, that a similar result was obtained when the water was cooled to temperatures between 32° and 22°; thus, when water cooled to the temperature of 27° was agitated, it was found that a twenty-eighth part of the whole mass was congealed. In this case, the whole mass was raised through 5° of the thermometric scale; and, since the heat developed by the frozen portion would be sufficient to raise twenty-eight times that portion through 5° of the thermometric scale, it follows that the frozen portion should be the twenty-eighth part of the whole mass: a conclusion which the experiment of Dr. Thomson fully confirmed."

By an extensive course of experiments, performed by various scientific men, the latent heat of many liquids has been ascertained, as well as the temperatures at which the process of liquefaction commences, and the expansion or contraction in freezing.

Of all the common and generally useful metals, tin and lead melt at the lowest degree of heat. The former of these metals begins to melt at a temperature of 442°; and according to Dr. Irvine, receives in its liquefaction as much heat as would, if made sensible, raise its temperature 500°: lead melts at a temperature of 594°. Tables of the melting points of several solids have been formed, as determined by philosophers in this and other countries.

The effect of extreme cold is not a little singular. It has been stated by some of our voyagers in the Arctic regions, that there were times in which it became rather a painful experiment to touch any metallic substance in the open air with the naked hand. The feeling produced by it exactly resembled that occasioned by intense heat; and, like its opposite, it took off the skin from the part affected: great caution was necessary in handling the sextants and other instruments, particularly the eye-pieces of telescopes, which, if suffered to touch the face, occasioned an intense and burning pain. There was, however, an easy remedy for this, by covering them over with soft leather.

A gentleman, who passed some years at Hudson's Bay, was carrying a key in his hand in the open air; and having occasion to use both hands for some purpose, he incautiously placed the key between his lips, when the rapid abstraction of heat produced the burning sensation alluded to; the skin adhered to the metal, and several weeks elapsed before he recovered from the consequences of the accident.

Mr. Pepys, who made several experiments some years ago in freezing mercury by a mixture of snow and muriate of lime, inadvertently taking up a piece of the solid metal, experienced a sensation as if he had received a wound from a rough-edged instrument. He threw it from him, he says, as he would have done a piece of red-hot iron; and he was not a little alarmed when he found that the part of his hand which had been in contact with the metal, immediately after lost all sensation, and became white and dead to the view.

On the 8th of February following, Mr. Pepys repeated the experiment on a much more extensive scale, and succeeded in freezing fifty-six pounds of mercury into a solid mass. He alludes in the following terms to the effects produced by touching the frozen metal: —

"The eagerness of our friends, of whom several were present, to be in possession of pieces of the solid mercury, was past description. Forgetting, and perhaps not being aware of the consequence, some rushed their hands into the frigorific mixture, while some seized on pieces which others, having selected with their eyes as their prize, also laid hold of at the same moment, and consequently each grasped them harder than otherwise they would have done. The acute pain that instantly followed, quickly recalled their recollection, and, but for the sufferings of the individuals, the scene would have excited no small degree of mirth: some clapped their hands into their mouths, others shook them, blew on them, or rubbed them against their clothes; and all were more or less alarmed at the dead appearance of the parts that had been so suddenly robbed of heat by the frozen metal." Mr. Pepys adds in a note:—"What is very singular, almost every individual compared the sudden pain he experienced to that produced by a burn or scald. One gentleman, who called accidentally while we were preparing for our experiment, but who had no acquaintance with the subject, not being able to conceive how the effect could be produced by the mixture, was desired to take a little snow in one hand, and muriate of lime in the other: they were neither of them colder than he expected to find them; then to put the *snow* into the hand that held the muriate. The ingredients had hardly come into contact when he threw them from him, exclaiming, 'Cold!—'tis a red-hot coal!'"

From a general survey of nature, and from the revelation which God has made of himself in his holy word, every man must be conscious that no natural law has been established without an adequate object; and it is probable that the reader will be anxious to know, what benefits result from the necessity for a certain amount of latent heat previous to liquefaction. Water is the most abundant agent in nature, and may therefore be chosen as best suited to illustrate the wisdom, benevolence, and even necessity of this arrangement. If ice were converted into water the moment its temperature is lowered to 32°, the devastation upon the surface of the earth would be greater than can even be imagined. Trace the mountain rills forming themselves into torrents, and the torrents sweeping away all impediments to their progress, joining to form rivers, the results of the slow melting of snow and ice round a mountain's cap; and then imagine that a different condition of nature had been established — that in a moment, without the slightest preparatory notice, the whole mass could be melted, and the importance of the existing agency will be perceived. But it is not necessary to refer to such instances as that we have mentioned, or to the effects which would be produced in high latitudes, where the frost reigns undisturbed the larger portion of the year; for even in this country, where the frosts are not severe, compared with many others, the phenomena which would attend a thaw would be more dreadful than any with which we are now acquainted.

Many effects resulting from the absorption of heat in liquefaction might be mentioned; the remarks on this subject shall be closed by an allusion to one.

It is a common remark, that it is more cold and chilly during a thaw than when it is freezing; this is not a vulgar fancy, it is literally true, and the cause may now be easily explained. When the temperature of the atmosphere after a severe frost begins to rise, the ice rapidly melts; but that this process may go on, heat must be supplied, for without latent heat there can be no liquefaction. To obtain this, it takes the sensible heat of all the substances with which it is connected, or with which it is in contact, reducing their temperatures. Now, after a severe frost, when a district or country is covered with ice, the amount of heat taken from the atmosphere must be considerable, and the coldness thus produced is very great; hence the air is colder during a thaw than when the water is absolutely freezing.

CHAPTER X.

VAPOURS—THERE IS NO DESTRUCTION OF MATTER—EFFECT OF PRESSURE IN BOILING—THE FOUNTAIN OF HIERO IN HUNGARY—THE GEYSERS OF ICELAND—THE STEAM-ENGINE.

VAPOURS are those elastic fluids produced from substances which, at ordinary temperatures, and under ordinary pressures, are solid or liquid.

To illustrate this, pour into a glass flask a small quantity of water, and place the vessel over a spirit lamp or any other source of heat. As soon as the liquid begins to boil, and the vessel is filled with the vapour of water, close the mouth so that the vapour may not escape. Let the heat be continued, and the water will diminish in quantity, and at last entirely disappear, so that the flask will appear to be empty. But let it now be removed from the lamp, and suspended in some cool place, a deposition of moisture will soon be observed over the inside of the vessel, and in a short time there will be as much water at the bottom of the flask as there was at the commencement of the experiment.

It is not unworthy of remark, that, whatever change of condition there may be in any substance, there can be no destruction of matter. The flask when filled almost to bursting with the highly elastic vapour, appears to be empty; but if it be weighed when the water is first introduced, and before the heat is applied, and again when the water has been converted into steam, no difference of weight will be detected.

The low temperature at which water boils may be shown by the use of an air pump. Under the receiver of this useful instrument place a small glass vessel, containing some hot water, a few degrees below the boiling point, and abstract some of the air; the water will soon be thrown into a state of violent ebullition. Air pumps are usually provided with a guage, so that the pressure of the internal air may be measured; and with such an instrument the influence of the atmosphere upon the boiling point may be easily determined, by taking the temperature of the water and the pressure of the atmosphere at the same time.

If water, or any other liquid, be exposed to a pressure greater than that of the atmosphere, its boiling point will be raised, and a higher temperature will be required to produce ebullition. This fact may be proved by the use of an instrument represented in the

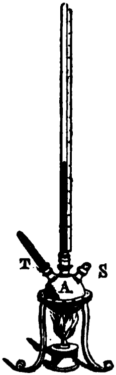


figure. A is a strong brass vessel supported on a convenient stand, so made that a lamp may be applied to the bottom of the vessel. In the top of the vessel there are three apertures, one for the introduction of a thermometer, T, the bulb of which enters the vessel; another provided for a stop-cock, S, which may be opened or closed at pleasure; and a third, which is in the centre, to receive a long barometer tube, open at both ends. Into the bottom of the vessel is poured some mercury, and the lower end of the tube dips into it. To put the instrument into operation, some water is poured into the vessel, and the stop-cock being closed, heat is applied. The temperature of the liquid is soon raised, and steam begins to form, but this being confined, exerts its pressure upon the surface of the water, and prevents ebullition. It is the property of all fluids to exert a pressure by their expansive force, which is in every direction equal. The steam, therefore, which is generated by the heat, presses downward upon the water from which it arose, as well as upon the interior surface of the vessel above the level of the water. In consequence of this downward pressure, the mercury is driven up the open tube, and soon appears above the vessel. As the pressure increases, the mercury rises, and in a short time will be observed to stand at a height of thirty inches above the level of the mercury in the metal vessel, when there will be an internal pressure equal to two atmospheres; for the steam has an expansive force equal to, not only the weight of mercury it supports, but also the weight of the atmosphere, (as the tube is open,) which are together estimated at thirty pounds on every square inch. From the mercurial column the attention may be directed to the thermometer, which is now no longer confined to the degree indicating a boiling temperature, 212°, but the mercury being at the height of thirty inches, will indicate a temperature of 250° Fahrenheit.

It must now be observed, that, during the whole time that this increased pressure is acting upon the surface of the water, there is no ebullition, which would be evident if the vessel were transparent, and may be as certainly known from the absence of that bubbling sound, so well known, which is the constant attendant of boiling. This may, however, be made more evident by the removal of the pressure. Let the stop-cock be opened, when the mercury stands at the height of fifteen inches, and the steam will instantly escape with a loud noise, the thermometer and the barometer, at the same time, falling; the one sinking to a temperature of 212°, the mercury of the other disappearing altogether. As soon as the equilibrium of internal and external pressure has been established, the well-known sound of a boiling liquid will be heard, which may be again hushed by closing the communication with the external air, and accumulating pressure by the confinement of aqueous vapour.

The powerful effects of high-pressure steam are illustrated, on a small scale, by the little glass bubbles, commonly called candle or fire-crackers: they are hermetically sealed, and contain a drop of water, which, when sufficiently heated, occasions them to burst.

In gases, it is observable that, while condensation produces heat, rarefaction produces cold. When hot steam suddenly issues, under great pressure, from a small aperture into the atmosphere, its instantaneous expansion so far cools it, that, if the hand be held in it, so far from scalding, it scarcely feels warm. Another instance appears in the Fountain of Hiero, as it is called, at Schemnitz, in Hungary.

A part of the machinery for working these mines is a perpendicular column of water, 260 feet high, which presses on a quantity of air enclosed in a tight reservoir. The air is consequently condensed to an enormous degree by this height of water, and, when a pipe communicating with the reservoir of condensed air is suddenly opened, it rushes out with extreme velocity, instantly expands, and, in so doing, it absorbs so much heat as to precipitate the moisture it contains in a shower of very compact snow, which may readily be gathered on a hat held in the blast. The force of this is so great, that the person who holds the hat must lean his back against the wall to retain it in its position.

In Iceland, some singular results of volcanic action are discoverable. There are vents, or aqueous craters, which discharge streams of boiling water or columns of steam. The chief of these are at Haukadal, far behind Mount Hecla, the snow-clad summits of which are, however, within sight. Within a very limited space, a great number of these geysers, or hot-spouting springs, the name being derived from the Icelandic verb to rage, to burst forth violently, are apparent, and the clouds of vapour they emit are visible at the distance of several miles.

One is called "the great geyser," a name to which, as the largest in Iceland, it is fully entitled. A large mound, formed of the various substances it has ejected during the lapse of ages, surrounds it. This mound is hollow, in fact a basin, about one hundred and fifty

THE GEYSERS.

feet in circumference, commonly having in it about four feet of boiling water, which is beautifully clear. A pipe or funnel, about ten feet in diameter, but wider at top, descends perpendicularly in the middle of the basin to the depth of nearly eighty feet in the earth, and is the vent of the boiling stream. From the sides of the basin two small channels open, and allow almost constant passage to some of the water, which, still hot, and strongly impregnated with mineral substance, flows, on leaving the mound, through a turfy kind of soil, and acting on the peat, mosses, and grass, gradually produces some of the most beautiful specimens of petrifaction. Leaves of the birch, and of other trees growing in that inhospitable clime, are also found incrusted, so as to appear of white stone, yet still preserving their minutest fibres unchanged.

The eruptions of this geyser occur at irregular intervals; the first signals of violence are low reports, and slight concussions of the earth. A few jets are now thrown up by the pipe, and after a pause a rumbling is heard beneath; louder reports succeed, with concussions strong enough to shake the whole mound, in the midst of which the water boils with increased violence, and overflows the edges of the basin. Other reports follow, louder and more rapid than the preceding, something like the discharge of artillery. With an astounding roar and immense velocity, the water then rushes through the pipe, and rises in the air in irregular jets, surrounded and almost concealed by volumes of steam. Loftier and more defined jets succeed to the first, and there is generally a central jet, exhibiting a column of boiling water from nine to twelve feet in diameter, and on an average from fifty to seventy feet in height. These boiling fountains seldom play longer than six or seven minutes at a time; then the action of the central pipe ceases; dense steam covers for a while the basin; and when that moves off, nothing is seen but a sheet of clear hot water, and all is quiet, until after an interval of some hours a fresh eruption is announced by faint reports. We are indebted for our information on this subject to Dr. Henderson, who visited the great geyser some years ago. On his second visit, when he pitched his tent close to it for two days, its eruptions occurred pretty regularly every six hours, and some of the columns of water rose to the height of one hundred and fifty feet.

That marvellous machine, the steam-engine, depends for its action on the alternate admission of steam above and below the piston, working in a cylinder, as will be clear from the following figure.

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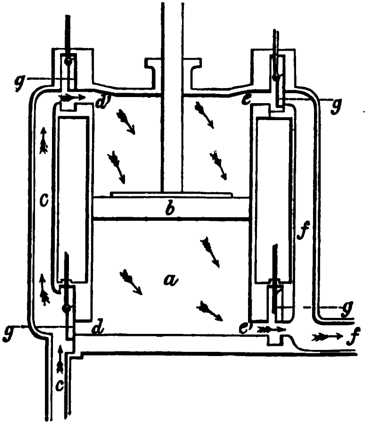
THE RAIL-ROAD.

a, cylinder; *b*, piston; *c c*, pipe by which the steam passes from the boiler to the cylinder; *d d*, passages to admit the steam alternately to the upper and lower parts of the cylinder; *e e*, passages by which the steam escapes from the cylinder through the pipe, *f f*, to the condenser: *g g g g*, slides for the opening or closing of the passages. The arrows point out the course of the steam as rising from the boiler through the pipe, and pressing on the upper part of the piston; and, also, as passing from the lower part of the piston to the condenser.



Much of the usefulness of the steam-engine is owing to the genius of Watt. Alluding to those who consider him the improver of this machine, Lord Jeffrey says, "He may rather be described as its *inventor*. It was by his inventions that its action was so regulated as to make it capable of being applied to the finest and most delicate manufactures, and its power so increased as to set weight and solidity at defiance. By his admirable contrivances, it has become a thing stupendous alike for its force and its flexibility, for the prodigious power which it can exert, and the ease, and precision, and ductility, with which it can be varied, distributed, and applied. The trunk of an elephant that can pick up a pin or rend an oak, is as nothing to it. It can engrave a seal, and crush masses of obdurate metal like wax before it; draw out, without breaking, a thread as fine as gossamer, and lift a ship of war like a bauble in the air. It can embroider muslins, and forge anchors; cut steel into ribands, and impel loaded vessels against the fury of the winds and waves." Its application to rail-roads has taken place since this statement was made.

CHAPTER XI.

EVAPORATION—RAIN—COOLING OF APARTMENTS IN THE EAST—ICE MAKING NEAR CALCUTTA—THE CLOUDS—WATER SPOUTS.

The process by which a liquid, at a common temperature, is converted into a vapour, is called evaporation, and it is one of those important and universal operations of nature, on which the proper action of all animate and inanimate creation depends. Instances of its beneficial operation are always before us; vegetable existence, and even the very fruitfulness of the earth are dependant on its continued and active influence. It is as necessary, also, for the healthful action of physical life, as perspiration is to the comfort and activity of the functions of the animal body.

Here we may recall the words of the poet:—

Behold how lovely shine the gems of rain,
Like sparkling diamonds on the glittering plain!
How, hanging on the flowering shrubs they blaze,
And dart beneath the leaves their silver rays!
The plants refresh'd, their flowers to heaven disclose,
As grateful for the good its hand bestows.

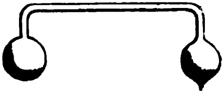
Referring to the God of providence, Job says: "He bindeth up the waters in his thick clouds; and the cloud is not rent under them," Job xxvi. 8. Thus, as Charnock remarks, " God compacts the waters together in clouds, and keeps them by his power in the air against the force of their natural gravity, till they are fit to flow down upon the earth, and perform his pleasure in the places for which he designs them. 'The cloud is not rent under them:' the thin air is not split asunder by the weight of the waters contained in the cloud above it. He causes them to distil by drops, and strains them, as it were, through a thin lawn, for the refreshment of the earth; and suffers them not to fall in the whole lump, with a violent torrent, to waste the industry of man, and bring famine upon the world by destroying the fruits of the earth. What a wonder would it be to see but one entire drop of water hang itself but one inch above the ground, unless it be a bubble which is preserved by the air enclosed within it! What a wonder would it be to see a gallon of water contained in a thin cobweb as strongly as in a vessel of brass! Greater is the wonder of Divine power in those thin bottles of heaven, as they are called, (Job xxxviii. 37,) and therefore called his clouds here, as being daily instances of His omnipotence. That the air should sustain those rolling vessels, as it should seem, weightier than itself; that the force of this mass of waters should not break so thin a prison, and hasten to its proper place, which is below the air; that they should be daily confined against their natural inclination, and held by so slight a chain; that there should be such a gradual and successive falling of them, as if the air were pierced with holes like a gardener's watering pot, and not fall in one entire body to drown or drench some parts of the earth—these are hourly miracles of Divine power, as little regarded as clearly visible."

The diminution of atmospheric temperature, and the cooling of the earth, are not, however, produced by the mere fall of water from the clouds, but by the evaporation which immediately follows: the rain is converted into vapour, and to obtain the heat which is required, the temperature of the earth and the surrounding atmosphere is lowered. The effect of evaporation in the production of cold, may also be shown by surrounding the bulb of a thermometer with a sponge moistened with water, or still better with ether, and then exposing it to the rays of the sun, or to the heat of a fire. The thermometer will instantly begin to fall from the rapid evaporation. A similar process is employed in the East to moisten and cool the atmosphere in the apartments of dwelling-houses. Curtains are used to separate one place from another instead of walls, and these being kept in a moist state by sprinkling them with water, a rapid evaporation goes on, and the temperature is considerably lowered.

In the extensive plains near Calcutta, ice is made, although the temperature of the atmosphere is great, by the judicious application of the principles of radiation and evaporation. Pits about two feet deep, and thirty feet square, are dug, and in the bottom of them is placed the dried straw of Indian corn, or the stalk of the sugar-cane, to the depth of about one foot. On this nonconducting bed unglazed earthen vessels, about an inch and a quarter deep, are placed, and into these water which has been boiled is poured. During the night, by the united influence of radiation and evaporation, the temperature of the liquid is reduced, and ice is found in the morning. The ice is then removed and carried to a pit, which is lined with straw and woollen substances, so as to prevent any conduction of heat, and thus to keep it from melting.

In hot countries, where cold water is one of the greatest luxuries which can be enjoyed, the inhabitants adopt the principle of evaporation in an ingenious manner, not as the result of their scientific investigation, but of experience; although it is by no means improbable, that a knowledge of philosophical principles may have taught the early nations from whom this and other methods have descended for centuries from generation to generation. The water is placed in porous earthen vessels, that the liquid may penetrate the substance. These vessels are then hung up in some place where there is a considerable current of air. The evaporation from the exterior surface of the jars, as well as from the liquid itself, reduces the temperature of the water, and preserves it fit for use. In travelling over the deserts, water is carried in earthen vessels, and the vessels are surrounded with moist cloths. The ancient Egyptians employed the same means for cooling their liquids.

The known principles of evaporation are admirably applied in many branches of manufacture, such as in the refining of sugar, and in the cooling of wort in the process of brewing. A still more familiar instance of its effects may be traced in the result of sleeping in a damp bed. Every one is aware of the fact, that it is dangerous to the health to sleep upon, or surrounded by, things which are moist; but of the cause many persons do not think it necessary to inquire. The animal system is provided with a means of generating a heat sufficient for the support and comfort of life, but when the surface of the body is surrounded by moisture, a portion of the animal heat is abstracted in the vaporization of this liquid. This can only be done by lowering the temperature of the body, and this is effectually accomplished, as the very means by which heat was to be preserved to the body tends to diminish it.



Dr. Wollaston invented an elegant little instrument, which he called the cryophorus: it is admirably adapted to exhibit the effects derived from evaporation. The instrument consists of a glass tube, about two feet in length, at both ends of which a bulb has been blown. The tube being thus prepared, the ends are turned at right angles to the length, one bulb being closed, the other being left open. The bulb that is closed is then nearly half filled with water, which being made to boil, fills the whole of the tube with vapour, driving out the atmospheric air. Let the bulb that remains open be then closed, and the instrument will be ready for use.

If, now, the empty bulb be immersed in a mixture of snow and salt, the vapour will be condensed, and a vacuum produced. The removal of pressure from the water in the other bulb causes a rapid evaporation, which is continued without diminution, as the vapour is condensed as fast as it is formed. The temperature of the water is thus reduced, and it is ultimately frozen; not from the freezing mixture, but from the diminution of sensible heat by the process of evaporation.

The appearance of the store-houses of vapours, if so they may be termed, has often attracted attention. Milton looks from the clouds to their Author, when he says,

Ye mists and exhalations that now rise
From hill or streaming lake, dusky or gray,
Till the sun paint your fleecy skirts with gold,
In honour to the world's great Author rise,
Whether to deck with clouds th' uncoloured sky,
Or wet the thirsty earth with falling showers,
Rising or falling, still advance His praise.

Bloomfield describes the appearance of clouds, on a fine moonlight night:—

Low on the utmost bound'ry of the sight,
The rising vapours catch the silver light;
Thence fancy measures, as they parting fly,
Which first will throw its shadow on the eye,
Passing the source of light; and thence away,
Succeeded quick by brighter still than they.
For yet above these wafted clouds are seen
(In a remoter sky, still more serene)
Others, detached in ranges through the air,
Spotless as snow, and countless as they 're fair;

Scattered immensely wide from east to west,
The beauteous semblance of a flock at rest.
These, to the raptured mind, aloud proclaim
Their mighty Shepherd's everlasting name.

The height of the clouds is caused by the expansive agency of heat, by which the water is raised from the earth in the form of vapour. Heat combines with water wherever it finds it, and forms a new kind of fluid, which, from its great elasticity, springs forth in every direction. And so, apart from some check, evaporation would go on till every drop of water on the face of the globe had entirely disappeared. But here we behold again the order of the God of wisdom; the wonder is, not merely that the water should be kept aloft, but that it should ever descend at all; as, when changed into vapour, it has a tendency to flow off continually, and not to return to the point from which it started. But this is held in check by means at once simple and admirable; as the effect is always proportioned to its cause, the quantity of vapour must depend on the quantity of heat contained in it. Now, this heat can never be greater than that of the atmosphere; for the moment the vapour in any region becomes warmer than the air around, the latter begins to draw off the excess of heat, and the vapour, which before

THE WATER-SPOUT.

was ascending in a thin transparent form, falls back in the shape of a cloud; and afterwards, if the heat continues to be withdrawn, descends in drops of rain. Thus, from the effect of heat, water ascends towards the sky, and from cold in the atmosphere it descends as rain.

In concluding these remarks, it may be well to notice the singular appearance of water-spouts. Dr. Franklin supposed that water-spouts and whirlwinds proceed from the same cause. A fluid moving from all parts horizontally towards a centre, must at that centre either mount or descend. If a hole be opened in the bottom of a tub filled with water, the water will flow from all sides to the centre, and there descend in a whirl; but air flowing in or near the surface of land or water, from all sides towards a centre, must at that centre ascend, because the land or water will hinder its descent.

CHAPTER XII.

SCENES IN AUTUMN—SPECIFIC HEAT—THE CALORIMETER—PREPARATION OF FOOD—MANUFACTURE OF GLASS—VALUE OF IRON—SPECIFIC HEAT OF GASES—THE MER DE GLACE.

THE influence of heat, so apparent in the spring, to which allusion has already been made, is powerfully exerted in autumn, of which a poet has said :—

> Season of mirth and mellow fruitfulness,
> Close bosom-friend of the maturing sun;
> Conspiring with him how to load and bless
> With fruit the vines, that round the thatch'd eaves run;
> To bend with apples the moss'd cottage trees,
> And fill all fruit with ripeness to the core;
> To swell the gourd, and plump the hazel shells
> With a sweet kernel; to set budding more,
> And still more, later flowers for the bees,
> Until they think warm days will never cease,
> For summer has o'er brimmed their clammy cells.

The season now referred to is one of great activity among those whose subsistence depends on rural toil.

> Waked by the gleamings of the morn,
> Soon clad, the reaper, provident of want,

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[illegible]

[illegible] compared [illegible]
[illegible] y been made, is [illegible]
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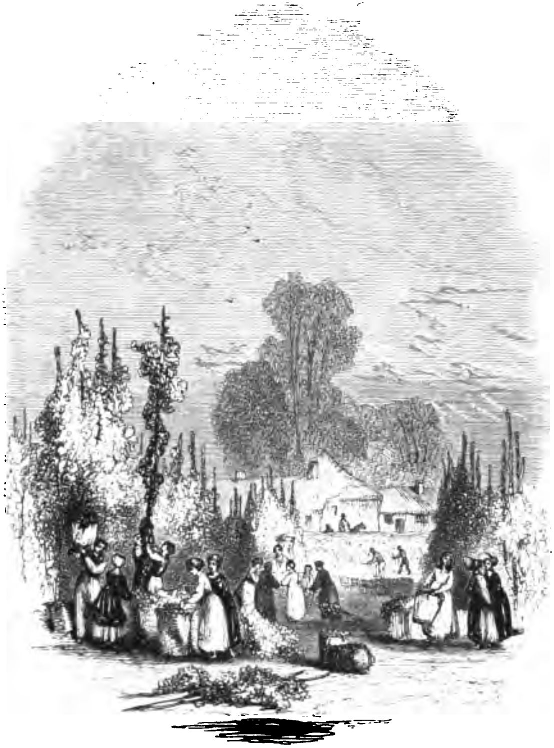


AN AUTUMNAL MORNING.

Hies cheerful-hearted to the ripen'd field.
Nor hastes alone; attendant by his side,
His faithful wife, sole partner of his cares,
Bears on her breast the sleeping babe; behind,
With steps unequal, trips her infant train:
Thrice happy pair, in love and labour join'd!
  All day they ply their task, with mutual chat
Beguiling each the sultry tedious hours.
Around them falls in rows the severed corn,
Or the shocks rise in regular array.
  But when high noon invites to short repast
Beneath the shade of sheltering thorn they sit,
Divide the simple meal, and drain the cask:
The swinging cradle lulls the whimp'ring babe.
Meantime, while growling round, if at the tread
Of hasty passenger alarm'd, as of their store
Protective, stalks the cur with bristling back,
To guard the scanty scrip and russet frock.

The time of hop-gathering is also a season of great interest and activity; it is known by the plants giving a strong scent, and the seeds becoming firm and of a brown colour. Men, women, and boys are employed at the same time. The greatest part of the hops cultivated in England, is picked by people who come from Wales for this purpose every year.

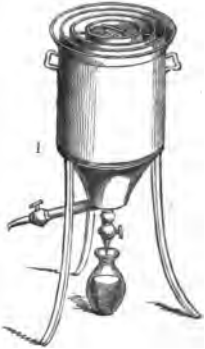
Various indeed are the fruits of the earth; the garden, the orchard, the field, yield richly their produce; would that He whose sun sheds far and wide its influence, and whose rains fall so richly and freely, received the tribute that is due to His name!

Other facts, in which the influence of heat appears, may now be noticed. The earliest experiments that were made on the capacity of bodies for it were performed by Fahrenheit, at the suggestion of Boerhaave. He discovered that, when equal quantities of a liquid, having different temperatures, were united, the temperature of the mass was a mean of the two; but this was not the case, when equal quantities of different fluids were mingled together. Thus, for instance, if a pint of water at one temperature be united to a pint at some other temperature, a common or mean temperature will be the result. If, on the other hand, two equal quantities of water and quicksilver be united, the water being the hotter, the temperature produced will be higher than the mean between the two; but, if the quicksilver be hotter than the water, the temperature will be less than the mean. Three parts, by volumes of quicksilver, are required to two of water, to produce a mean temperature. These facts are, in themselves, so curious, that the attention is immediately attracted by them, for they open to the mind a class of inquiries singularly connected with the very constitution of matter. Judging without experiment, any person would say that, when equal quantities of water and quicksilver were united, a mean temperature would be established between them, in precisely the same manner as when equal quantities of water are used. Such, however, is not the case, and we are led inevitably to the conclusion drawn by Boerhaave, when he was first informed of the facts we have mentioned, that the quantity of heat possessed by bodies does not depend on their quantities of matter. This is evident, as an equal bulk of quicksilver does not raise the temperature of the mixture so high as water, although it is thirteen times heavier.

The quantity of heat required to raise the temperature of a substance from one degree to any other degree, depends on the nature of the substance and its capacity for heat. The amount thus required is called the specific heat of the body.

Lavoisier and Laplace, in their experiments on specific heat, employed an instrument which they called a calorimeter. A description of the construction of this apparatus and of the method of using it seems necessary as explanatory of the nature of the experiments, and will, perhaps, better convey a notion of the subject to the mind than any other method of illustration.

The calorimeter consists of three vessels, one within the other, as shown in figure 1. The two exterior are metallic, and are so formed that the interval between them may be filled as required. The inner vessel, if such it can be called, is an open wire cage, as shown in figure 2, and is intended to receive the substance, whatever it may be, on which the experiment is to be made. The instrument, however, will be better understood by reference to a section given in figure 3, which is a representation of it as it would appear if cut in halves, the interior being open to view. To this we shall refer in the explanations to be given in the following remarks.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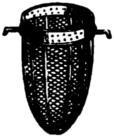
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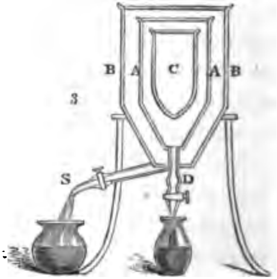
A and B are two metallic vessels, the former having a discharge pipe, D, and the latter a stop-cock, S, by which the liquid in the several vessels may be discharged at pleasure. Between these vessels there is no communication, for the discharge tube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from A passes through the bottom of the vessel, B, so as to be water tight, and a close cover is placed over the vessel, that there may be no communication from above. The outer vessel, B, is also furnished with a cover to exclude the atmospheric air. Now, let the vessel, B, or, in other words, the space between the vessels A and B, be filled with pounded ice, and, as it liquefies, the water may be discharged from the stop-cock, S; but in the process of liquefaction heat must be obtained, and that heat is derived not merely from the external air, but also from that in the interior of the vessel, A, so that, if a supply of ice be continued, the enclosed air of the vessel, A, cannot have a temperature higher than that of 32°. But the vessel A is intended to receive another vessel, which is the cage C; and the space which is not occupied by the cage is filled with pounded ice, in the same manner as the outer vessel. The purpose for which the ice is introduced into the outer vessel will now be evident: it is to keep the ice in the interior vessel at an equal temperature, so that it may be only affected by the substances placed in the cage; every other source of heat being excluded. To use the instrument, then, let any substance be introduced into the cage, and its excess of temperature above the freezing point will be communicated to the ice, a portion of which will be melted. The stop-cock of the discharging tube, D, being opened, the water produced by the liquefaction of the ice from the heat of the substance being made latent, will flow out, and its quantity will be proportional to the quantity of heat communicated by the substance enclosed in the cage.

The method of using the instrument will be best explained by an example. Let it be required, for instance, to ascertain the amount of heat necessary to raise the temperature of a piece of iron from 80° to 100° Fahrenheit. To do this a mass of iron must be brought to the higher temperature 100°, and in this state be placed in the cage, C, where it will be enclosed by a cover that fits tightly. A communication of heat immediately follows, and while the solid is falling to the temperature of 32°, a portion of the ice is melting. The liquid thus produced is then discharged into the receiver, and must be accurately weighed. Let it be supposed that the water weighs exactly an ounce. The iron is then removed, and being raised to a temperature of 80°, is again introduced into the calorimeter, where it is allowed to cool, the water produced being in like manner drawn off and weighed. Now, suppose that the water discharged this second time weighs half an ounce, and it necessarily follows that the heat required to raise the temperature of iron from 80° to 100° is equal to that which would be required to melt half an ounce of ice.

The different relation of heat to different substances is another of the arrangements to which we have so often had occasion to refer, of the all-wise and beneficent Creator. Suppose it, for a moment, to be wanting, and it will be seen at a glance that numerous evils would arise which are now happily averted. A few instances of its importance are all that can now be given.

The preparation of human food, so as to make it at once nutritive and agreeable, is peculiarly connected with the physical well-being of man in his social state. These ends are attained in proportion as it approaches nearer to the state of complete digestion, or to that which is termed chyme, whence the chyle or milky juice that afterwards forms blood, is absorbed and conveyed to the heart. Now, nothing is further from this state than meat and vegetables when raw; fire is therefore necessary to soften them, and to commence that process which is finished in the stomach.

In France the art of cookery is considered to be the practical result of no mean order of science. A work on this subject by M. Ude is pronounced, by competent judges, to be far too scientific for ordinary readers. On a contemporary professor of the culinary art, named

Carême, it is said the autocrat of all the Russias, when at Paris, bestowed a diamond ring — a tribute sometimes offered by the czar to men of distinction in genius and science. It must have been amusing to an ordinary spectator, to observe this man in the kitchen of his employer, seated at a high desk, surrounded by an elegant railing, like a Milanese banker, with his papers and recipes before him, issuing his orders to the various attendants under his command. Frequently too, there might be seen from the rank and file drawn up in battle array before the line of furnaces, an official advancing in a cotton nightcap, dimity jacket, and thin shoes, bearing on a silver salver two small plates of the same metal, one containing a little sauce, the other a small sippet of delicately white bread. This was respectfully presented to Carême, who, with the air of a prince, either said that it was good, or gave directions for its improvement.

After this reference to the culinary art, to take another instance of the operation of heat; how much are we indebted for many of the comforts of life to the use of glass! To say nothing of its aiding the vision of multitudes, and being instrumental to the most important discoveries in science, its value for domestic purposes is very considerable. Great indeed is the contrast between our present circumstances and those of 1567, when, in the minutes of a survey of Alnwick Castle, it was stated that because of extreme winds the glasses of the windows of this and other castles of its noble proprietor did decay and waste, it was good that, at the departure of his lordship, and during his absence, they should be taken down and laid up in safety, and that on his return they might be set up again with small charge, "whereas now," it is said, "the decaye thereof shall be verie costlie and chargeable to be repayred." In Scotland, so late as the year 1661, the windows of the ordinary country houses were not glazed, and only the upper parts of those of even the king's palaces had glass, the lower ones having two wooden shutters to open at pleasure and admit the fresh air.

The whole operation of the glass-house, however, depends on its furnaces. Here arrangements must be made to secure and control the agency of heat. Equal attention is required by the crucibles which are employed. Whatever be the form hereafter to be assumed by the glass, its materials must be fused, and in many cases the vessel that is formed must be repeatedly exposed to the action of fire.

The process of annealing is, also, one of very great importance, in which the same power is indispensable. Unless this were passed through, glass would be liable to fly with the smallest change of temperature, and would break with the merest scratch or touch, or even without any apparent external cause of injury. The reason of this is supposed to be that by the sudden cooling of unannealed glass, the external particles are forcibly contracted, while the inner substance continues soft and expanded. The positions of the two portions are thus very different from those that would be occupied had the contraction of the whole gone forward gradually and equally. As it is, a constant strain is kept up between the parts; and should a force, however simple, derange the equilibrium of resistance, the elastic quality of the glass causes the injury to be felt suddenly and strongly, yet still unequally, throughout the whole. An interesting illustration of this theory may here be given. The Bologna phial, as it is called, is made of glass; it is of an ordinary shape, is much thicker at the bottom than the top, and has been suddenly cooled in the air. The thickness of this lower part defends it from a considerable blow of any blunt instrument, and it will even bear upon it the sudden force of a leaden bullet. But should a small portion of gun-flint, or even a grain of sand be dropped into

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THE IRON MINE.

it, the bottom will crack all round, and drop off. This experiment has been made when the glass was very brittle, and a cut diamond dropped upon it, has been seen to pass through with apparently as little resistance as a cobweb would offer. On the other hand, this singular property has been destroyed by heating the phial to redness, and then suffering it to cool gradually as in the annealing oven. Not only was this result obtained, but the particles of glass became also more closely united.

Iron has been described as the great instrument of human civilisation. Now, the ore of this metal, when collected, is not in a fit state for use; the extraneous substances with which it is connected must be removed, and this is done by exposing it to the action of heat in a process called smelting. The smelter, in performing his task, by means of his furnace, lets off the iron into moulds prepared for the purpose; the casts thus produced are called pigs, and are ready for the use of the iron-founder. We require, also, the labours of the smith, and the cast-iron which the founder renders useful in a great diversity of ways; but it contains a large quantity of carbon, and other impurities, from which it must be freed to make it thoroughly malleable. Here heat must again be applied, and, when

MOUNT ETNA.

removed from the fire, it is subjected to the pressure of rollers, or the beating of large hammers, and is thus prepared to come into the market in bars or rods. Still our wants, as they regard this metal, are not all met. Steel is indispensable for many purposes; but, for this, wrought-iron, the iron used by the smith, must be slowly heated in contact with charcoal, that it may give off oxygen, and take up a portion of carbon. When steel is raised to a high temperature, and suddenly cooled, it becomes exceedingly brittle and unfit for use. It is, therefore, tempered, as the workman would call it; that is, it is heated again, and then cooled in water, at the proper temperature he requires. This is known by the colour the steel assumes. As it is of a light straw-colour under the action of heat, he knows that it has a certain degree of hardness; that degree is not so great, if it have on it a gold colour; and, when followed by a purple hue, which will appear if heat be continued, it becomes soft. The spring of a watch is an instance of this; it was cooled at the point at which this colour appeared, because it was the one showing that the steel was in the precise state adapted to this purpose.

The different capacity for heat of air in different states, is productive of effects of great importance. The air of the atmosphere, on the surface of the earth near

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the sea-shore, has a certain density; but on the top of a mountain fifteen thousand feet high, the air bears but half the pressure, and, therefore, twice the volume of an equal quantity at the sea-side. The temperature, too, is also many degrees inferior; for, as the air which is at any time on the mountain top may have been just before on the adjoining shore, and climbing up the mountain side, it must have expanded and cooled in proportion to the diminishing pressure. It appears that air, on first ascending from the sea-shore, becomes one degree colder for about two hundred feet of perpendicular ascent, and altogether about fifty degrees colder in rising fifteen thousand feet. Ætna, the far-famed burning mountain of Sicily, is divided into three districts or regions, each having its characteristic differences. They have distinct climates, corresponding with the gradations of ascent, and divided into the torrid, the temperate, and the frigid. The mountain has, however, been divided according to other differences, and thus we have described to us the fertile region, the woody region, and the barren region. The fertile region extends fifteen miles from the city of Catania, whence the traveller usually begins his journey, and from which part the ascent commences. The surface of this region is reckoned at upwards of two hundred and twenty square leagues. It abounds in pasture grounds, orchards, and fruit trees of great and rich variety, and there the vine especially flourishes. The next advance is to the woody region, which begins about three miles above the latter place, and extends upwards of eight or ten miles. The vegetation of this part is said to increase as you advance, the trees gradually diminishing in size, till they become dwarfish and insignificant. This region is estimated at from seventy to eighty miles in circumference, with a surface of about forty or fifty square leagues, forming a girdle round the mountain of vivid green, composed of oaks, beeches, and other trees, in a soil of vegetable earth. The climate is here most agreeably mild, the air is cool and reviving, and every breeze is filled with delicious odours.

Lofty mountains are usually covered with snow. As at the height of fifteen thousand feet, water is frozen even near the equator, where the temperature near the sun is eighty-four degrees, a line might be traced dividing the portion of a mountain to be covered with snow from that where vegetation shall flourish. This is called the snow line, or line of perpetual congelation. In lofty regions, glaciers are formed. The snow near the upper part of the broad line of congelation, having been only softened or partially thawed in the preceding summer, becomes in winter almost as solid as ice, and in the following summer vast masses, detached by the action of the sun and of the heat of the earth, are constantly falling down into the valleys beneath. Such accumulations, and the filling up of the crevices with snow or water, which hardens into ice, forms, at last, the seas of ice which render certain regions so remarkable. The Mer de Glace of Switzerland is, in fact, a vast glacier or defile of ice, from half a mile to a mile in breadth, running in different directions, between huge mountains, to the extent of about five leagues, and supposed to vary in depth from one to three hundred feet. It may be said to bear the appearance of a lake, wrought into tumult and fury by whirlwinds, and then instantaneously frozen, presenting various elevations, some being fifty or sixty feet, consisting of misshapen crags, ridges, and pyramids of ice, generally of a dull blue cast, with points and edges tinged of a sea-green hue, glittering in the sunbeams with various prismatic colours, the whole icy chaos being everywhere cleft into fissures of a fearful depth, and interspersed with rocks, which have tumbled from the overhanging mountains.

The falling of vast masses of ice, called in Switzerland avalanches, attended with tremendous explosions, which re-echo like thunder among the mountains, are of frequent occurrence during the summer; when the imprisoned waters, formed by the melting snows and ices, burst forth anew, undermine the mass, and bring down enormous fragments of the glacier. About fifty years ago, three travellers imprudently ventured to fire a pistol within the entrance of one of these icy caverns, when, through the vibration it occasioned, an immense fragment was immediately detached, and fell on the unhappy party, one of whom was crushed to death, and the other two severely injured.

The diminished temperature of the air in higher regions, often affords to the dwellers for a time in tropical climates the means of restoring their health when it has been impaired. Dr. Arnott mentions a visit he paid to the island of Pinang, in the strait of Malacca, with great pleasure. The centre is occupied by a lofty and thickly-wooded mountain ridge, on the summit of which a few residences, visible like eagles' nests on a cliff, had just been constructed. One morning at sunrise, he began, on an active little horse, to climb to these, along a tolerable road, from the hot plain below.

At first there were around merely tropical objects, inspiring tropical feelings, the latter modified by the reflection that his track lay through a forest, into which, until recently, the foot of man had never ventured; and where the trees, nursed through ages to their greatest growth, and the stupendous precipices and a noble waterfall had recently been exposed to observation. But as he gradually ascended, the character of the vegetation was found to be changing, and the air to become so light and cool, as irresistibly to awaken in him thoughts of distant England, nay, even almost to produce the illusion of his being there.

At last, however, the summit being reached, where a clear space opened to view the whole country around, the attention was quickly recalled to the fervid land of the sun. The elevation is so great, that at first the eye takes account of only the grander features of the scene, and such merely as might be met with on a Grecian or Italian shore: the expanse of many waters in that beautiful strait, stretching so far north and south; the opposite continental shore, with its river winding seaward across the plain; the town and the roadstead near it, crowded with ships, which appeared only as specks in a wide-spread map, etc.; but, on closer inspection, and particularly with the aid of the telescope, were descried the rich groves of cocoanut and banana, the plantations of spice, and cotton, and sugar-cane, the tawny labourers, the bamboo dwellings, the fanciful canoes or prows; in a word, every object bespeaking the torrid zone.

CHAPTER XIII.

SOLAR PHOSPHORI—FIRE—GURNEY'S BLOWPIPE—A SHIP ON FIRE —VOLCANOES—EARTHQUAKES—THE END OF ALL THINGS.

A SHOEMAKER of Bologna, named Vincenzio Cascariolo, had occasion to calcine a quantity of a species of native sulphate of baryta, found at Monte Paterno in his neighbourhood. He noticed, that whenever the spar had been sufficiently heated, it acquired the property of shining in the dark, after having been exposed to the sun's rays, and that it would even continue thus to emit light for some hours. In consequence of this accidental discovery, the spar was greatly in request among the curious; and the best mode of preparing the Bolognian phosphorus became a subject of no small pecuniary importance.

Other substances possess similar properties, of which one is Canton's phosphorus, made by calcining oyster-shells in the open fire for half an hour. These solar phosphori, as they are called, have their luminous power diminished by cold, and increased by heat. They are more brilliant in dry and warm, than in wet and cold weather: they shine most intensely after exposure to direct sunshine; but some of them exhibit their phosphorescence when carried into a dark place after exposure to common daylight. Moonlight cannot render them luminous; but the flash of gunpowder, the light of a bright candle or lamp, or an electric explosion, suffices to make them shine more or less intensely.

There are other phosphori which become luminous when moderately heated, that is, at a temperature below a red heat; only a few of this large class, however, are eminently luminous. Of these, the compact phosphate of lime, found native near Estramadura in Spain, and certain kinds of fluor, or Derbyshire spar, especially the dark blue and slightly fetid variety, are the most remarkable. The former exhibits a beautiful pale-green light, bright enough to be seen in the daytime, and the latter shines with a purple tint.

It is desirable to look from such cases to a gift of incalculable value. Man has been called a fire-making animal, because he alone of all creatures is able to kindle and sustain fire, and to employ it for useful purposes. Travellers light fires to drive away wild beasts from the spots where they take up a temporary abode, and this device is successful; many of the inferior animals are fond of warmth, but they are unable to provide it artificially for themselves. Here we recognize another wise arrangement of Providence, but for which incalculable evils must inevitably have arisen.

The Chaldeans accounted fire as a divinity, and in the province of Babylon, there was a city called Ur, or "of fire," devoted to its offering. The Persians also adored God under the symbol of fire, because they considered this to give motion to everything in nature, and they had pyræa, or fire-temples, set apart for the preservation of the sacred element. The Guebres, or Parsees, as they are called, scattered by persecution from Persia, in which they arose, sought a refuge on the shores of India. Some, however, determined to remain; their great fire-temple, called Altush Kudda, is near Badku, one of the largest ports in the Caspian sea. In the neighbourhood of this town, the earth is impregnated with naphtha, a mineral oil, to which the inhabitants owe their fuel and light. Around the principal fire, the whole ground, for a circumference of about two miles, may be inflamed by a burning coal. Here arise burning springs, which the people apply to domestic purposes; by sinking a hollow cane or tube of paper about two inches in the ground, and by blowing on a hot coal, held near the opening of the tube, a slight flame issues, which neither burns the cane nor the paper. At this flame they boil water in their coffee-urns, and even cook different articles of food. Various other purposes are secured by the same means. Sometimes the whole country around Badku appears as if enveloped in flames. It often seems, indeed, as if the fire rolled down from the mountains in large masses, and with incredible velocity, and, during the clear moonshine nights of November and December, a bright blue light is observed, at times, to cover the whole western range. Nor is it the least remarkable fact, that the fire does not consume; and, if a person finds himself in the middle of it, no warmth is felt.

Allusion was made, at the commencement of this volume, to combustion as a source of heat; it must now receive more particular attention. The word thus employed is one of those terms used in science, and in the ordinary conversation of life, in different senses; and, indeed, there are but few persons who give it precisely the same meaning. According to some writers, combustion happens whenever a substance unites with the gas called oxygen, light and heat being given out; but, according to others, the term may be applied to any chemical change between the elements of matter in which light and heat are developed. This latter application of the word is the more correct, because it acknowledges what is known to be true, that combustion may occur without oxygen, or, in other words, that there may be chemical changes, with the development of heat and light, without the presence of oxygen.

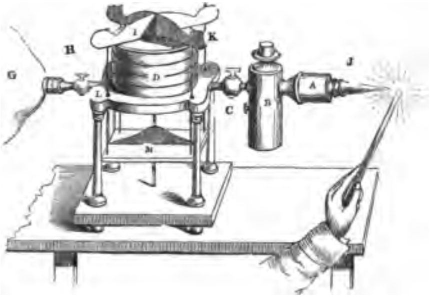
There are many persons who entertain a very erroneous opinion concerning combustion, and speak of it as though it were the absolute destruction of matter. This opinion has even been conveyed to the ordinary and standard expressions of facts and appearances. Thus we say the coal is burning away, the candle has burned out, and, as it were, perpetuate the error which philosophers, in times that are past, were accustomed to teach. The coal on the fire is not destroyed, but the simple substances of which the coal consists are separated and assume new forms, and not one atom of them is lost. It would even be possible to collect all the elements, during combustion, and thus ascertain the composition of the substance; although it is beyond the art of the chemist, in most cases, to recombine the disunited elements, and reproduce the compound body.

Nearly all substances may be brought into a state of combustion under favourable circumstances, but this cannot happen unless oxygen, chlorine, bromine, or iodine be present. These substances are, therefore, said to be supporters of combustion. A few experiments in illustration of this important fact, may be here described.

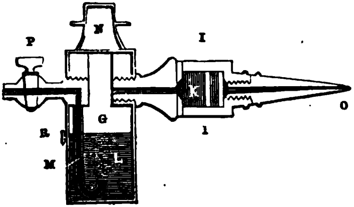
Atmospheric air is composed of two gases, oxygen and nitrogen; but it is the oxygen alone that supports combustion. Take a small glass receiver, a tumbler, or any other vessel open at one end and closed at the other, and invert it over a piece of lighted paper or candle, in any shallow vessel, such as a soup plate, and the flame will soon decrease in size and brightness, and be at last extinguished; for all the oxygen has been chemically combined during the process of combustion, and the nitrogen alone is left in the jar, which is not a supporter of flame.

Take a glass vessel, open at one end, and having a ground glass stopper at the other, as shown in the figure, and fill it with pure oxygen gas. Then attach to a cork which fits the opening a piece of iron wire, and to this fasten a lighted paper, or any other body in a state of combustion, and, when introduced into the oxygen, the brilliancy of the combustion will be greatly increased.

A most intense heat may be obtained from the combustion of the two gases oxygen and hydrogen, in the proportions to produce water, which is generally performed in an instrument called the oxy-hydrogen blowpipe. These mixed gases are among the most explosive compounds in nature, and it is, therefore, exceedingly dangerous for any young person to attempt to experiment with them. Many serious accidents have been occasioned by their use, even to those who are accustomed to all the precaution and care which become habitual after a long-continued attention to experimental investigations. When the oxy-hydrogen blowpipe was first used in public, the experimenter was cautious to have a brick wall between him and the vessel which contained the mixed gases, so fearful were all men of the danger of explosion. Habit soon produced confidence, and attempts were made to diminish the danger, and place this formidable, yet desirable agent, within the reach and management of a careful experimenter. This was, in a great measure, effected by Mr. Goldsworthy Gurney. The instrument has since attracted much of the attention of scientific men, who are now accustomed to use the gases in separate vessels, which has lessened still more the danger of their use; but the possibility of explosion is not, we believe, altogether prevented. As the combustion of oxygen and hydrogen is now employed for the production of an intense light, as well as heat, a light sufficient to exhibit on a splendid scale microscopic objects, we will describe the two forms of instruments; one in which the gases are mixed in the same vessel as in Gurney's blowpipe, and the other in which they are kept in separate vessels, and only permitted to unite the instant previous to combustion.

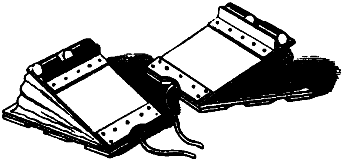


The figure is a representation of Gurney's blowpipe, which the inventor himself thus describes. A and B are the safety apparatus, of which the figure on page 189 exhibits a section, and through which the gas must pass from the gasometer D by the stopcock C. G is a transferring bladder screwed to the stopcock H, by which the gasometer is charged by an assistant during its action, and such a quantity of gas supplied as to keep up a flame for any requisite time. Between the gasometer and the charging bladder a valve is placed, to prevent a return of the gas. I is a wood or pasteboard cap, so contrived as to unite lightness with strength; this is attached by four strings, K, to wires, which, passing through holes, L, in the table of the instrument, are fixed to M, a moveable press-board below. When the requisite pressure or weight is placed on M, the cap I is drawn down horizontally and equally on the gasometer D, upon which the gas is forced through the water tube B, the safety apparatus A, and out of the jet J, at the end of which it is burned. If an explosion were to happen in the gasometer, the cap I would be thrown into the air, where, from its extent of surface and great lightness, its progress would be arrested before any mischief ensued. The gasometer bladder, or silk bag, D, is tied to a bladder piece which screws into a tube contained in the body of the table of the instrument. This tube terminates in the stop-cocks C and H. The next figure is a section of the parts A B of the preceding figure enlarged. P is the stop-cock which admits the gas from the gasometer to the water-trough, G, by a tube M, which reaches to the bottom of that vessel. L is the water with the gas rising through it. B is a gauge, which indicates the proper height of the



water; N is a cork, which, if an explosion happen on the surface of the water, is thrown up, or which can be taken out when water is to be poured into the trough; I I, are chambers in the safety apparatus, intended, by means of the wire gauze partitions, K, to arrest the progress of a retrograde flame; O is the jet, of which various sizes should be provided, to be used at the will of the operator.

The method of keeping the gases separate is shown in this figure. The oxygen and hydrogen are conveyed by separate tubes to any distance that may be required, when they are united, so that the two gases at last flow through the same channel to the point where they are brought into combustion. If an explosion, therefore, should occur, it will be in the union tube, and cannot extend to the vessels; for the gases they hold are



not explosive, so long as they are kept from mixing, which cannot very easily occur, as the upper of the two boards, between which the mackintosh bags are placed, is pressed by sufficient weights.

From these remarks, then, it is hoped, the reader will understand the nature of the operation in the oxy-hydrogen blowpipe, and the cause of danger. When the combustion is produced in contact with the atmosphere, from a small jet, a quiet, steady, and most intense combustion is the result; but, should a flame, or even a spark, be thrown, by any means, into a reservoir containing the mixed gases, the entire volume of the mixture will explode, and with such violence of expansion as greatly to injure, in all probability, the persons who are standing near. We have known instances in which windows have been blown out, and even roofs carried away by the ignition of large volumes of the oxy-hydrogen mixture.

A few experiments may now be mentioned, by which the intensity of the heat produced by the combustion of the mixed gases may be proved. In performing the experiments we are about to mention, charcoal must be used as a support when one is required, as it is the only substance which can at all resist the intense heat.

Place upon a piece of charcoal, prepared for the purpose, some small globules of platinum—a metal which is now well known from its constant use in philosophical and chemical experiments—and direct upon it the full stream of ignited gases. The metal will soon be reduced to a liquid state, and the several globules will unite and form one mass. Dr. Clark has in this manner melted two hundred grains of platinum, forming a single metallic globule of extreme brilliancy. When it is remembered that this substance is not to be liquefied, except by the highest degree of temperature which can possibly be obtained by artificial means, the result of the experiment is very remarkable.

Bring into the flame of the blowpipe a riband of steel, such as a watch-spring, and a brilliant combustion, attended with bright scintillations of light, will follow.

Copper, when placed on the charcoal, and brought under the action of the blowpipe flame, is fused, and burns rapidly, giving out a delicate green flame. The nitrate of copper is used by fire-work manufacturers, to produce in a combustible compound the green hue which is sometimes elegantly introduced.

Silver, when melted before the blowpipe, burns with a bright green flame; and gold exhibits the same colour, but has a more intense hue.

Take a piece of flint or quartz rock, and burn it in a furnace; it may then be reduced to a fine powder. Let this powder be moistened with water, and afterwards exposed to the heat of the blowpipe flame, the several particles will soon be agglutinated, and will shortly after be fused into a colourless glass.

When the flame is thrown upon lime, a light is produced so splendid and intense, that the naked eye cannot support the rays. This substance is used in the oxy-hydrogen microscope, and it is by its intense combustion that the bright and well-known light is obtained. The lime itself, however, may be reduced by the heat.

These are a few of the many experiments which may be made with the oxy-hydrogen blowpipe, but are sufficient to prove that an intense heat is given out during the combustion of the two gases, oxygen and hydrogen, when mixed in the proportion to form water.

With conflagration in various circumstances, we are familiar: to mention only one case, a striking description of a ship on fire may be given from the pen of the late Sir T. S. Raffles. He was about to proceed from Bencoolen to England; he thus writes:—"The ship was everything we could wish; and having closed my charge here much to my satisfaction, it was one of the happiest days of my life; we were, perhaps, too happy, for in the evening came a sad reverse. Sophia (Lady Raffles) was just gone to bed, and I had thrown off half my clothes, when a cry of 'Fire! fire!' roused us from our calm content, and in five minutes

THE SHIP ON FIRE.

the whole of the ship was in flames. I ran to examine whence the flames principally issued, and found that the fire had its origin immediately under our cabin. 'Down with the boats!' 'Where is Sophia?' 'Here!' 'The children!' 'Here!' 'A rope to this side!' 'Lower Lady Raffles!' 'Give her to me,' says one: 'I'll take her!' says the captain. 'Throw the gunpowder overboard!' 'It cannot be got at; it is in the magazine, close to the fire!' 'Stand clear of the powder!' 'Skuttle the water-casks!' 'Water! water!' 'Where's Sir Stamford?' 'Come into the boat, Nilson! Nilson, come into the boat!' 'Push off! push off!' 'Stand clear of the after part of the ship!'

"All this passed much quicker than I can write it. We pushed off, and as we did so, the flames rushed out of our cabin window, and the whole of the after part of the ship was in flames. The masts and sails now taking fire, we moved at a distance to avoid the immediate explosion; but the flames were now coming out of the main-hatchway, and seeing the rest of the crew with the captain still on board, we pulled back to her under her bows so as to be more distant from the powder. As we approached, we perceived that the people on board were getting into another boat on the opposite side. She pulled off—we hailed her; 'Have you all on board?' 'Yes, all save one.' 'Who is he?' 'Johnson, sick in his cot.' 'Can we save him?' 'No, impossible.' The flames were issuing from the hatchway. At this moment, the poor fellow, scorched, I imagine, roared out most lustily, having run upon deck. 'I will go for him,' says the captain. The two boats then came together, and we took out some of the persons from the captain's boat, which was over-laden; we then pulled under the bowsprit of the ship, and picked the poor fellow up. 'Are you all safe?' 'Yes, we have got the man—all lives safe!' 'Thank God! pull off from the ship!' 'Keep your eye on a star, Sir Stamford; there is one scarcely visible.'

"We then hauled close to each other, and found the captain fortunately had a compass, but we had no light except from the ship. Our distance from Bencoolen we estimated to be about fifty miles in a south-west direction. There being no landing-place to the southward of Bencoolen, our only chance was to gain that port. The captain then undertook to lead, and we to follow, in a north-north-east direction as well as we could, no chance, no possibility being left that we could again approach the ship; for she was now one splendid flame, fore and aft, and aloft, her masts and sails were all in a blaze, and rocking to and fro, threatening to fall in an instant. 'There goes her mizen-mast! pull away, my boys!' 'There goes the gunpowder!' 'Thank God! thank God!'

he?' 'J[illegible] sick in [illegible] we save him?' 'No, imp[illegible]' The [illegible] were [illegible] from the hatchway. At this moment [illegible] down, scorched, I imagi[illegible] deck. [illegible] the captain. [illegible] two bo[illegible] together, and we [illegible] of th[illegible] over-[illegible] under the [illegible] ship [illegible] safe [illegible] 'T[illegible] or [illegible] there is one [illegible] to each [illegible] c[illegible] compass, but we [illegible] dist[illegible] from [illegible] miles in a [illegible] to the [illegible] was to [illegible] that [illegible] north-north-east [illegible] no possi[illegible] left that [illegible] the ship; for she was now one [illegible] aft, and [illegible] masts and [illegible] and rocking to and fro, the [illegible] her mizen [illegible] boys! [illegible] the gunpowder! [illegible] thank God!'

THE EARTHQUAKE.

"You may judge of our situation without further particulars; the alarm was given about twenty minutes past eight, and in less than ten minutes she was in flames. There was not a soul on board at half past eight, and in less than ten minutes afterwards she was one grand mass of fire."

In conclusion, allusion may be made to earthquakes, which arise from the power variously illustrated throughout this volume. Volcanoes appear to be closely connected with them. In the earthquake of Lima, in 1746, four volcanoes opened in one night. It is generally found that the deeper seated the explosive force is, the greater is the concussion.

We hear of the ravages produced by an earthquake with various emotions; we shall be the spectators of changes unspeakably more awful. In a moment, the last day will burst on the astonished world: intense splendour will mark the approach of the Son of God. The judgment will be set, and the books opened; and when the final allotments of angels and men are determined, the doom of this great world will come. All the works of man, his palaces and temples, his cities and villages, with all the displays of art in which he gloried, will be lighted up, and then vanish from creation.

Nor will this be the only desolation: "The elements shall melt with fervent heat;" and from the face of Him that is seated on "the great white throne," "the earth and the heaven shall flee away, and there shall be found no place for them." But amidst this vast and final conflagration, multitudes will be secure and joyous. They have fled for refuge to the cross of Christ, and arrayed in his righteousness, and bearing in their ransomed souls his image, they may say, as they stand on the ashes of the universe, "We have lost nothing; our inheritance is incorruptible, undefiled, and fadeth not away: the heaven we sought as pilgrims and sojourners on earth is secure for ever, and the duration of our glory and happiness is that of our God." May he who writes, and they who read, through infinite mercy, be found among them! The course on which the righteous enter is one of the highest wisdom. What a compensation have they even here for every trial and every sacrifice! And oh! what folly marks the path of the transgressor! "For what shall it profit a man, if he shall gain the whole world, and lose his own soul? or what shall a man give in exchange for his soul?"

THE END.

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